ECONOMIC DEVELOPMENT ADMINISTRATION

TECHNICAL
ASSISTANCE
PROJECT

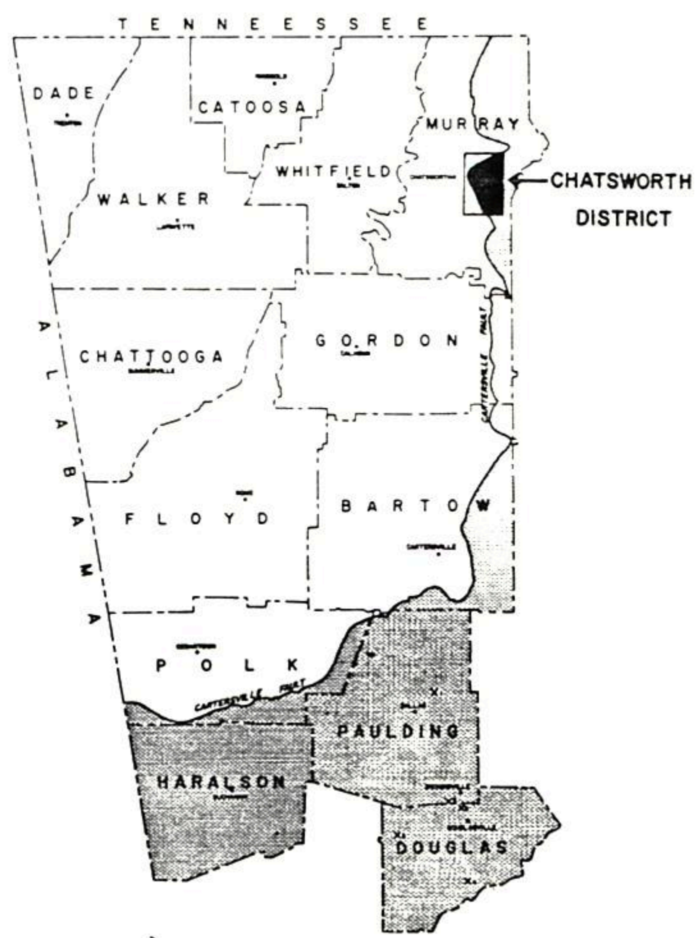
U.S. DEPARTMENT OF COMMERCE

TALC DEPOSITS IN THE COOSA VALLEY AREA, GEORGIA

BY ROBERT E. NEEDHAM
VERNON J. HURST

Geology Department
University of Georgia

in Cooperation with the
Coosa Valley Area Planning
and Development Commission,
Rome, Georgia and the
Economic Development
Administration
United States Department
of Commerce
Washington, D. C.
March 1970



SUMMARY

The study of talc deposits in the Coosa Valley area began in 1966 as part of a broader study under contract with the Coosa Valley Area Planning and Development Commission, Rome, Georgia, and the Economic Development Administration, Washington, D. C.

The Coosa Valley area comprises 13 counties in northwest Georgia — Bartow, Catoosa, Chattooga, Dade, Douglas, Floyd, Gordon, Haralson, Murray, Paulding, Polk, Walker and Whitfield. Talc has been found in 3 of these: Douglas, Murray and Paulding. The occurences in Douglas and Paulding originated through metamorphism of dikes and small pods of ultrabasic rocks and are not competitive with the larger masses of metasedimentary "talc" in Murray County. Thus the study of commercial talc in the Coosa Valley area condenses to the study of talc in Murray County, where all known occurrences are in the Chatsworth district.

The Chatsworth district is underlain on the east by Pre-Cambrian metasedimentary and metaigneous rocks which have been sliced by several major faults and thrust along the Cartersville Fault, which runs roughly N-S, onto Conasauga shales and limestones of lower Cambrian age to the west.

The talc is in a metasedimentary unit, the Cohutta schist, which has been intruded and largely engulfed by the Fort Mountain gneiss. The trend of the schist is clear on the accompanying geologic map, though only remnants remain. A total of 26 remnants have been mapped, three of which currently are being mined. The longest continuous exposure is 1500 feet. About half the strike distance of the talcose unit is covered by scree and slope wash deposits, which might conceal workable deposits. Major faults cut off the Cohutta schist on both the north and south sides of the district; no reappearance beyond either cut-off has been found.

The Cohutta schist generally is a fine-grained, green, schistose chloritic rock containing variable amounts of sericite, actinolite, calcite, dolomite, and other minerals, as well as bands and lenses of talc. The bodies of relatively pure, straight-grained talc are mined for <u>Crayon talc</u> or <u>saw talc</u>. The <u>white grinding talc</u> consists of several minerals, principally talc and dolomite, which yield a soft white powder when ground. The <u>dark grinding talc</u> is essentially talc, chlorite, serpentine, sericite, and lesser percentages of other minerals which yield a gray powder when ground. For both, soft and hard grinding varities are distinguished.

The pockets of pure talc generally are found where dips change, as along flexures in the Cohutta schist. The best talc exposure, the new Rock Cliff Mine, is on a local warp at Gold Mine Branch. The same is true at the Mill Creek Mine and the Earnest Prospect. Several old mines that superficially were located on good leads became inoperative when the talc pinched out or when the grade became too low. Examples are the Upper and Lower Bramlett Mines, Latch, and Big Lindsay; these are located where the strike of the Fort Mountain gneiss parallels the regional trend.

The best prospects for future exploration are the northward extension of the Rock Cliff Mine lead, the Earnest Prospect, the Old Chicken Creek Mine, and the underground connection of the Georgia, Old Cohutta and Judge's Hole Mines.

The Earnest Prospect contains high grade material at the south end of the lead. Drilling is needed to prove the ore downdip, because of the possibility that a thrust sheet shallowly underlies the area.

Exploration at the Chicken Creek Mine should include drilling to the south to determine thickness and downdip extent.

Neither drilling nor clearing is feasible at the Georgia - Old Cohutta - Judge's Hole area due to the steepness of the slope. The underground connections to be prospected could pay their way because much of the mined material could be ground as filler. In particular, drifts should be extended southward toward the Old Cohutta Mine where high quality talc once was mined.

The Addendum contains information on the mineralogy of talc, its mining, processing, marketing and utilization, imports-exports, prices, and general outlook.

CONTENTS

FIGURES

TABLES

ADDENDUM ON TALC

INTRODUCTION

In June of 1966 the Geology Department, University of Georgia, contracted with the Coosa Valley Area Planning and Development Commission and the Economic Development Administration to conduct a partial survey of mineral resources within the Coosa Valley Area, Georgia. The survey was restricted to three classes of deposits: carbonates, sulphides, and talc. After two years of study, the findings have been assembled as three separate reports, one for each class of deposits.

This report deals with talc: description of mines and prospects, talc utilization since mining began in 1872, extensions of the known deposits, and the location of new deposits.

Thirteen counties in northwest Georgia -- Bartow, Catoosa, Chattooga, Dade, Douglas, Floyd, Gordon, Haralson, Murray, Paulding, Polk, Walker, and Whitfield -- totalling 4,171 square miles are included in the Coosa Valley Area. Paleozoic rocks which never have been subjected to the temperature-pressure conditions required for the formation of talc underlie Catoosa, Chattooga, Dade, Floyd, Walker, Whitfield, and the western portions of Bartow, Gordon, Murray and Polk Counties. Thus economic talc deposits are to be sought only in Haralson and Paulding Counties and the portions of Bartow, Gordon, Murray and Polk Counties underlain by metamorphic rocks east of the Cartersville Fault (Figure 1).

The principal talc deposits are in the Chatsworth District. Scores of occurrences outside the Chatsworth District have been mentioned in published and unpublished reports. All the reported occurrences have been checked, and many of them proven false. All the known shows outside the Chatsworth District originated through the metamorphism of dikes and small pods of ultrabasic rocks found at widely scattered points east of the Cartersville Fault. Metamorphism has yielded talc as a secondary mineral, along with anthophyllite, chlorite, magnesite and other minerals. The talc rarely constitutes more than a few percent of the rock. Good descriptions have been given by Hopkins (1914, p. 281-83). Though additional small ultrabasic masses might be exposed in time, those found so far are not competitive with the large, purer masses of metasedimentary talc. The likelihood of finding better deposits of this type is small. Thus the investigation of economic talc deposits in the Coosa Valley Area condenses to the study of talc in the Chatsworth District.

TALC OCCURRENCES

IN COOSA VALLEY AREA, GEORGIA

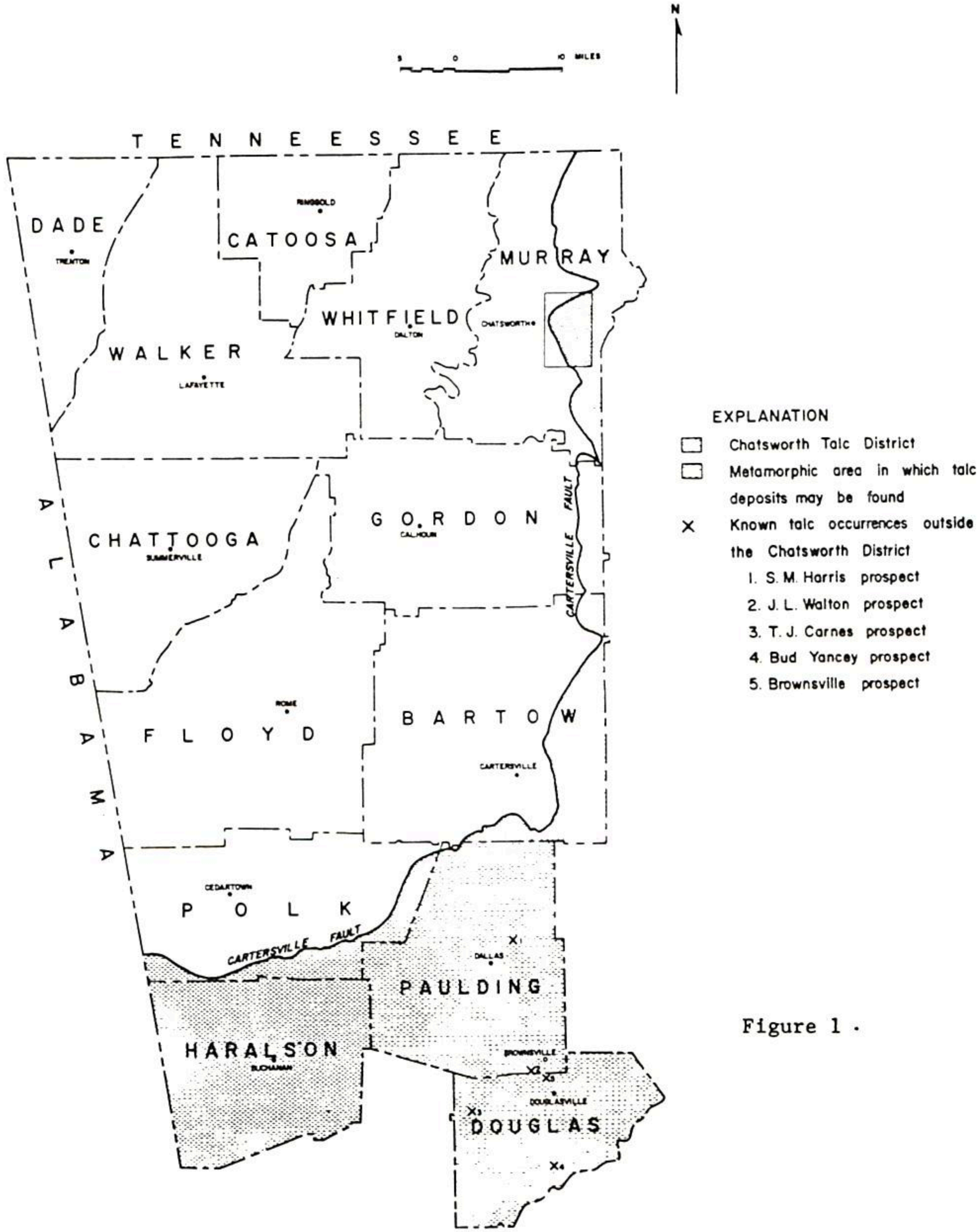


Figure 1.

PREVIOUS GEOLOGIC WORK

The first geologic map and description of the Dalton quadrangle, which includes the Chatsworth District, were prepared between 1889 and 1896 by C. W. Hayes. His unpublished folio is on file at the U.S. Geological Survey in Washington, D. C.

In 1914 Hopkins briefly described the talc deposits of the Chatsworth District in a report on "Asbestos, Talc and Soapstone Deposits of Georgia" (p. 243-267).

A geological reconnaissance of the district was made by Geoffrey Crickmay during preparation of the Geologic Map of Georgia, which was published in 1939.

The most comprehensive report is that by Furcron, Teague and Calver published in 1947. Their report includes a geologic map of the district, descriptions of the talc mines and prospects, and maps of the underground workings of four mines.

FIELD WORK FOR THIS REPORT

General field mapping began the 6th of September, 1966, when Dr. L. D. Ramspott commenced two weeks of field work in the southern part of the district. The mapping was continued by Mr. Robert Needham on a half-time basis during the second quarter, interrupted from mid-January through April, continued on a full-time basis by Mr. Needham from May through September, 1967, and on a part-time basis from October to January, 1968, when the field work was concluded. Aerial photographs were used as base maps.

After the known district had been mapped in detail and location of all talc shows plotted, the mapping was extended to the north, south, and east for several miles in the hope of finding additional occurrences. Reports of talc as far south as Ranger were investigated, but all proved false. No further occurrences of Fort Mountain gneiss or talc were discovered in the extended mapping area. The reported leads turned out to be either highly weathered phyllite or muscovite schist, or fuchsite, a green chromiferous mica commonly found along the west side of the Georgia Piedmont.

After the geologic mapping had been completed, all the existing mines and prospects were re-examined. A sketch of the Judge's Hole Mine was prepared. The Georgia Mine and the Earnest Mine were mapped geologically using survey plats provided by the Georgia Talc Company as base maps.

ACKNOWLEDGEMENTS

The cordial cooperation and assistance of Mr. Francis Glenn and Mr. M. Woodward Glenn and the assistance of Mr. Garvin Swanson and Mr. Sandy Harrison, Mine Foremen, are gratefully acknowledged.

GENERAL GEOLOGY

Precambrian metasedimentary and metaigneous rocks underlie most of the district. They are cut by major faults which have repeated the lithologies and thrust older rocks onto younger rocks. The Cartersville Fault, a prominent postmetamorphic thrust, bounds the Precambrian rocks on the west. Underneath the Cartersville Fault are Conasauga shales of lower Cambrian age. Farther west are Cambro-Ordovician shales, limestones and dolomites.

Pre-Cambrian Rocks

Cohutta Schist

The oldest unit is the Cohutta schist, a metasedimentary unit intruded and largely engulfed by the Fort Mountain gneiss. Only remnants appear to remain. Their trend generally parallels the margins of the enclosing gneiss. The accompanying geologic map shows the Cohutta schist cropping out as though it occupies no fixed position within the Fort Mountain gneiss. The largest exposures are about 1500 feet long. However, the pattern of present outcrops might not represent accurately the distribution of the schist, because more than half the total area that might be underlain by Cohutta schist is covered by talus from the mountain escarpments.

As originally defined (Furcron, Teague and Calver, 1947, p. 6), the Cohutta schist formation contains all the talc deposits of the Chatsworth district. This study shows that all of the talc is not simply the product of metamorphism of a dolomite sediment; part of it represents chemical interchange between the Cohutta schist and the Fort Mountain magma; some of the talc is a replacement of the Fort Mountain gneiss. Thus the Cohutta schist formation, as now defined, is not simply a metasedimentary unit but includes all the talc deposits regardless of their origin. The apparent random distribution of the talc, then, at different levels within the gneiss may be attributed to (1) folding and faulting, both of the Cohutta schist and the enclosing gneiss, (2) the more ready assimilation by the Fort Mountain gneiss of the Cohutta schist where its composition did not yield large amounts of amphibole, carbonate, chlorite or talc, and (3) to some extent the different processes by which talc formed. Certainly the distribution, shape, internal layering and mineral assemblages of the talcose zones connote their general origin through the metamorphism of a sediment. Still, the massive chemical interchange between the talcose unit and the Fort Mountain gneiss apparent at some localities and the partial replacement of the gneiss by talc at others show that all of the talc did not originate by a single process, and probably not at the same time.

In weathered outcrops the Cohutta schist is a fine-grained, green, schistose chloritic rock containing bands and lenses of talc. Occasionally needles of green actinolite up to one inch long are found. The talc is stained yellow or yellow-brown, but still has the characteristic greasy feel and can be carved easily with a knife. Talc boulders that long have been exposed to the sun are bleached a silvery gray color and may be mistaken for phyllite.

Within the talc mines, the Cohutta schist is seen to be mineralogically and structurally more complex than it appears in natural outcrops. Other minerals in addition to talc, chlorite and actinolite are common as calcite, dolomite, siderite, magnetite, pyrite, ilmenite, chrysotile, antigorite, nephrite, sphene, quartz, albite, microcline, biotite, muscovite, apatite, zircon, hematite, and even cordierite. Part of the mineralogical complexity apparently is due to the partial assimilation and reaction of the Fort Mountain gneiss magma with the Cohutta schist. Part of the talc mined as ore is clearly Fort Mountain gneiss in which carbonate minerals have replaced much of the albite and some of the microcline and chlorite and talc have replaced biotite. In this rock type the original accessory minerals in the gneiss — apatite, zircon, sphene, and ilmenite — are preserved.

Common rock types in the Cohutta schist are altered wall rock containing remnants of quartz and feldspar, schistose talc-chlorite rock, massive serpentine veined with carbonate, schistose actinolite, and talc containing 50% or more porphyroblasts of carbonate. The last is "white grinding talc" valued for its grindability and high brightness.

Fort Mountain Gneiss

Two distinct belts, both containing lenses and bands of Cohutta schist, have been mapped. East of the two belts is a small mass less than half a mile across in which no talc has been found. The gneiss is fairly uniform megascopically in lithology and texture and is considered to be an orthogneiss.

The fresh rock typically is coarse-grained with elongate augen of plagioclase and microcline 3-10 mm long and smaller, more nearly equant grains of clear to bluish quartz. The augen are set in a groundmass of very fine-grained biotite. The augen intersect the fissility of the rock to produce a distinct lineation.

In thin section the gneiss commonly exhibits a cataclastic texture: quartz grains have undulous extinction and may be polycrystalline; feldspar augen are broken, rotated, and bounded by quartz pressure shadows; the biotite is uniformly fine-grained and wispy. A typical specimen has the following composition:

Albite (Ab_{97})	-	35%
Microcline	-	12%
Quartz	-	25%
Biotite	-	25%
Accessories	-	3%

Accessory magnetite, sphene, apatite, and zircon are evenly distributed throughout. Within 50 feet of a talc body the gneiss may have its albite replaced by carbonate. The replacement may amount to 50% of the rock volume. Upon weathering the carbonate is leached out, leaving a boxy, light-weight saprolite often extensively jointed. Further evidence of carbonate leaching is the presence of brown, iron-stained stalactites around joints and old drill holes in mines. This weathered rock is distinctive and offers a larger "target" to the prospector than the usually thin talc sheets.

On low angle slopes where the fissility intersects the ground surface at a high angle, the gneiss is typically weathered to saprolite. In this condition the gneiss is distinctive in not producing a ground litter of rock chips. The saprolite is medium brown, and contains very small flakes of biotite. The augen structure is not always well preserved. Quartz pods and veinlets are rarely present in the gneiss and accordingly are scarce in the saprolite.

Amphibolite

A single band of amphibolite up to 30 feet thick has been mapped in the eastern belt of the Fort Mountain gneiss. East of the Earnest Mine the amphibolite is exposed only as a boxy saprolite and might be an amphibolitic rock related to the Cohutta schist. Fresh amphibolite is exposed along Georgia Highway 52 and near Sandy Gap.

The Sandy Gap amphibolite is composed of 60% hornblende in stubby, pleochroic, subhedral, intermeshing crystals, and 37% plagioclase of composition Ab_{68}, 2% ilmenite in rounded grains with leucoxene rims, and 1% apatite. The plagioclase is sausseritized and contains small crystals of clinozoisite. The rock is granoblastic with an average grain size of 0.6 mm. The rock contains numerous 1/8 to 1/4 inch wide quartz veins arranged in parallel bands. The quartz veins split hornblende grains and are thus of later origin.

The amphibolite could have originated as an intrusive dike in the Fort Mountain gneiss. Some of the talc-chlorite bodies might represent altered masses of amphibolite rather than altered Cohutta schist.

Ocoee Rocks

The Ocoee rocks are a thick sequence of metasediments unconformably overlying the Fort Mountain gneiss. Three subunits have been mapped.

Quartzites

This subunit consists principally of medium- to coarse-grained, quartzites which may be cross-bedded, but also includes light colored arkoses and quartz-feldspar conglomerates. The quartzites are well sorted and often thin-bedded. They may weather readily to white sand, as at Sandy Gap. The arkoses are more resistant and form cliffs along the tops of Fort and Cohutta Mountains. Their average grain size ranges from 2-5 mm and they contain roughly equal proportions of quartz and feldspar. The conglomerates contain quartz boulders up to two feet in diameter, though generally the pebbles are no more than 2-3 inches across.

Phyllites and Slates

The rocks of this subunit range from silvery gray to nearly black. The slates are commonly pyritic. The phyllites commonly are graphitic and knotty. The slates and phyllites disintegrate but otherwise resist weathering. An abundant float develops. Occasional beds of metagraywacke are found.

Schist

The schist is fine-grained and differs from the phyllite only by its more schistose structure. The schistosity generally is deformed, and rock chips that weather out are convex on both sides.

Cambrian Rocks

Conasauga Shale

On the west side of the Cartersville Fault are Conasauga shales of Cambrian age. The weathered shales are grey to yellow-brown, fissile, and usually soft. The unweathered shales are greenish and hard, and may contain several percent of carbonate. The fissility is highly deformed along the Cartersville Fault.

DESCRIPTION OF MINES AND PROSPECTS

Georgia Mine

Location and History

The Georgia Mine is about 3½ miles southeast of Chatsworth in Lot 271, on the west side of a low ridge.

Talc was discovered on Lot 271 about 1872. The Georgia Mine was opened in 1907 and has been mined continuously since that time. It has produced more talc than any other mine in the district.

Geology

The mine is located in a talcose unit (Cohutta schist) near the middle of a band of Fort Mountain gneiss. The talcose unit extends nearly a half mile south of the Georgia Mine and about the same distance on to the north, with a thickness as great as 150 feet in the vicinity of the Georgia Mine. Other mines have been opened in the Cohutta schist both to the north and to the south.

The strike of the talcose unit is fairly regular. Its dip varies from 5° to 90°, with an average of 32°. Neither large-scale folding nor major faulting are prominent, though small-scale faulting is prevalent, as shown by slickensided chlorite in all parts of the mine. Pockets of talc may occur where there are abrupt changes in dip. One example of this is on the south passage of the 5th level. Another example is at the tramway on the bottom level.

The Fort Mountain gneiss not only bounds the talcose unit but also occurs as small masses within it.

The mineralogical composition of the ore varies greatly within short distances along as well as across strike. This variability is illustrated in Figures 2 and 3. Figure 2 is a sketch of the north wall of the bottom level, near the loading platform (the point X in Figure 5). Figure 3 is a sketch of a heading on the second level, south passage, facing west (point Y of Figure 5). An average of samples collected from all the sketched lithologic units is:

Talc	36.9
Chlorite	32.7
Dolomite	12.9
Quartz	8.0
Magnetite	5.0
Plagioclase	3.0
Biotite	1.1
Apatite	0.4

At Y, part of the footwall was collected. Where the talcose unit is sufficiently thick the footwall is not mined, and the ore contains little quartz or plagioclase.

Mining

Many of the old openings made along or near the talc outcrop have been

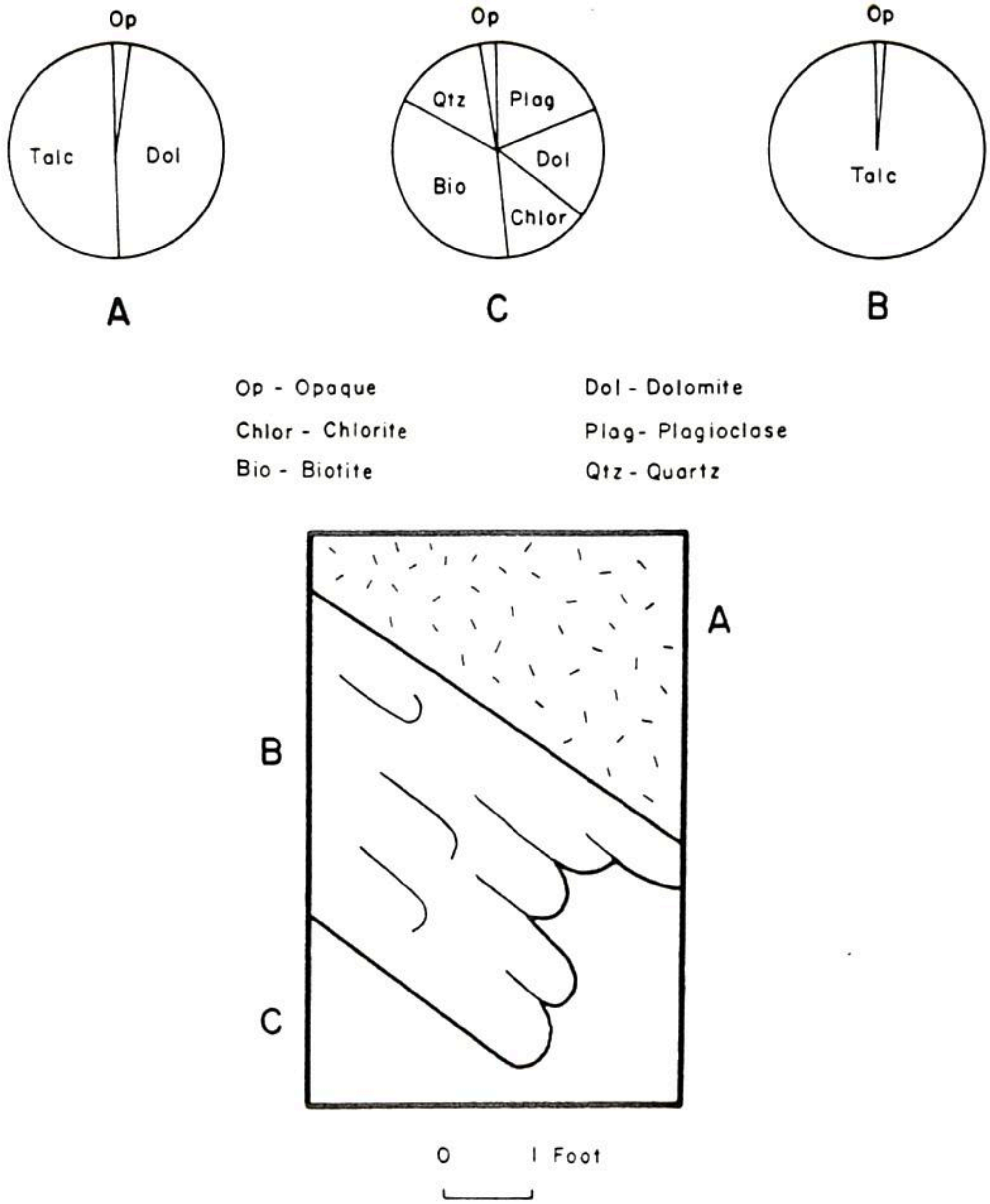


Figure 2 - Sketch and mineralogy of lithologic units within the ore zone exposed in the bottom level of the Georgia Mine, north wall, near the loading platform.

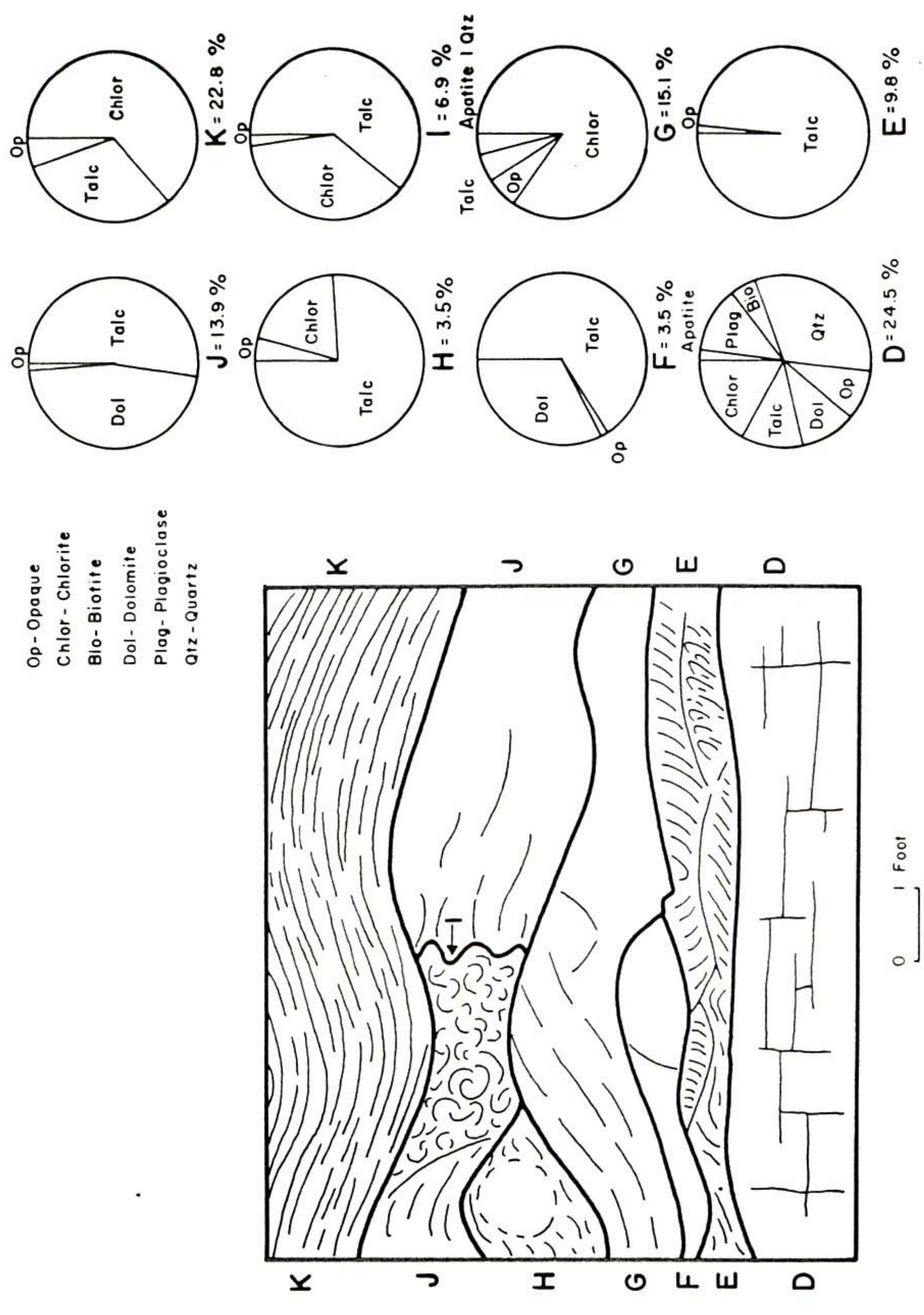


Figure 3 — Sketch & mineralogy of lithologic units within the ore zone exposed by a heading on the second level, south passage, facing west, Georgia Mine.

abandoned and are caved. Many of the early underground workings are caved. Figure 4, reproduced from Furcron, Teague and Calver (1947, Plate 2), shows the extent of accessible workings on the northern half of the property in 1947; the openings on the southern part of the lot were filled with water and inaccessible at that time. Figure 5 shows the present workings. This main opening was made by extending the old shaft to the surface. The topmost 100 feet (not shown on Figure 5) consists of small openings that were worked in the early years of the mine. Levels 6 through 2 were mined progressively, by tramcar methods, from the 1940's to the present. The bottom level is being mined now using a front end loader and dump truck that were disassembled and lowered down the haulage way. Future mining will be done by cutting gentle grades passable to the truck. The fork at the south end of the bottom level is for this purpose. The ore is dumped into a small capacity bin, transferred to the tramcar, and hauled to the surface where it is dumped into a large bin, and finally trucked to the mill. Pumps are used intermittently to rid the mine of water.

Future of the Mine

The mine map (Figure 5) shows the talcose unit thinning both to the north and the south and pinching out nearer to the main haulage way with increasing depth. At lower levels the quality of the talc is notably inferior than that mined at higher levels. So far no white grinding talc has been found at the bottom level.

Reserves of dark grinding talc are great. The talc of crayon grade so far encountered during mine development largely has been mined out.

Earnest Mine and Fort Mountain Mine

Location and History

These mines are located about 3.5 miles northeast of Chatsworth on the northwest slope of Fort Mountain in Lot 297 at an elevation of about 1900 feet.

Talc was discovered at the site prior to 1900. Early mining was confined to outcrops and was not extensive. About 1939 more extensive mining commenced at two openings about 1/8 mile apart known as the Fort Mountain Mines. In following the talcose unit at depth, sinuous, steep passages were dug which required double hauling, i.e., transferring the ore cars from one winch to another. Accordingly, a decision was made to drive a new entrance and to start mining with dump trucks and a front end loader. The new portal that was driven about 1962 is known as the Earnest Mine. The principal production has come from the portal several hundred feet northeast of the old Fort Mountain Mine, with which the Earnest Mine connects underground. The tunnel slopes up from the entrance and intersects the talc underground. Water has not been a problem; most of the lower passages are completely dry.

Geology

The structure is very complicated. Both boudin structures and tongues of biotite gneiss occur within the ore. The included biotite gneiss typically is rich in carbonates, calcite and dolomite.

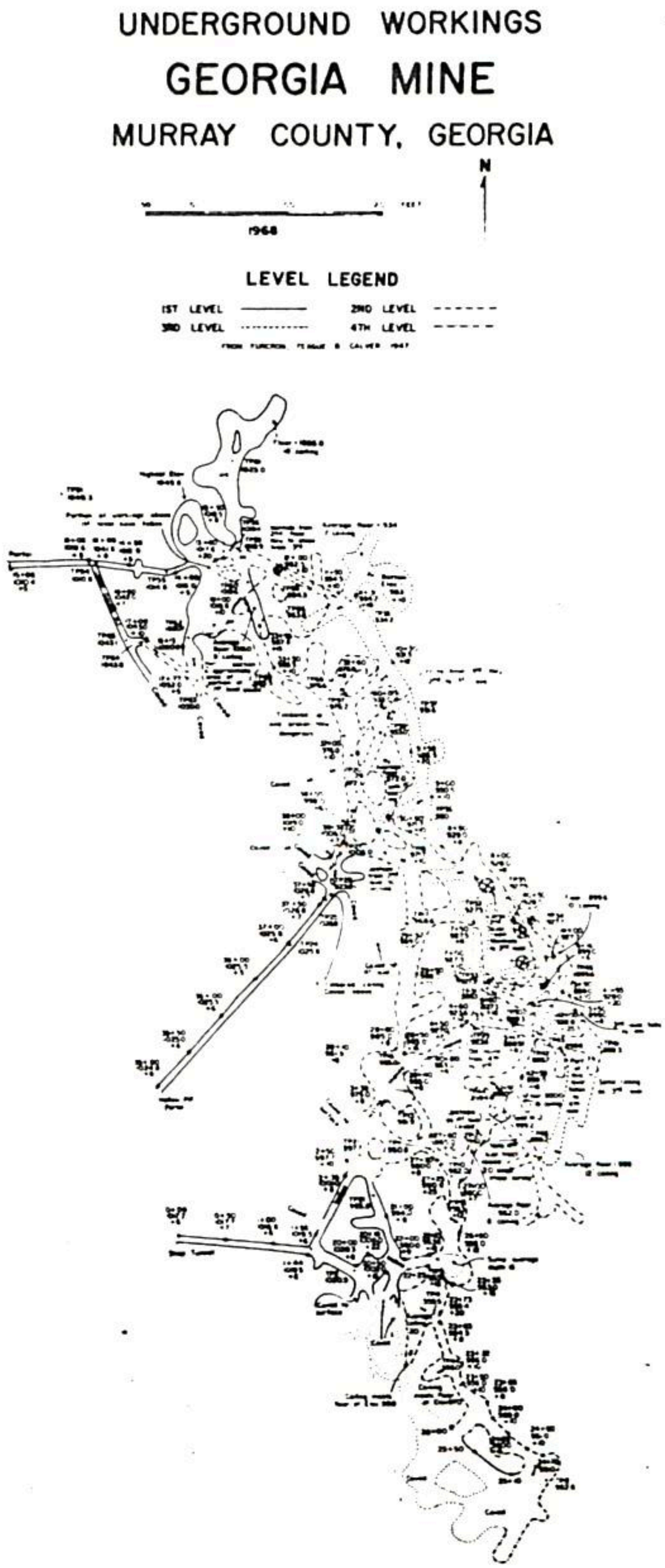

UNDERGROUND WORKINGS
GEORGIA MINE
MURRAY COUNTY, GEORGIA
N
1968
LEVEL LEGEND
1ST LEVEL
2ND LEVEL
3RD LEVEL
4TH LEVEL

Figure 4

GEORGIA MINE

CHATSWORTH DISTRICT, GEORGIA

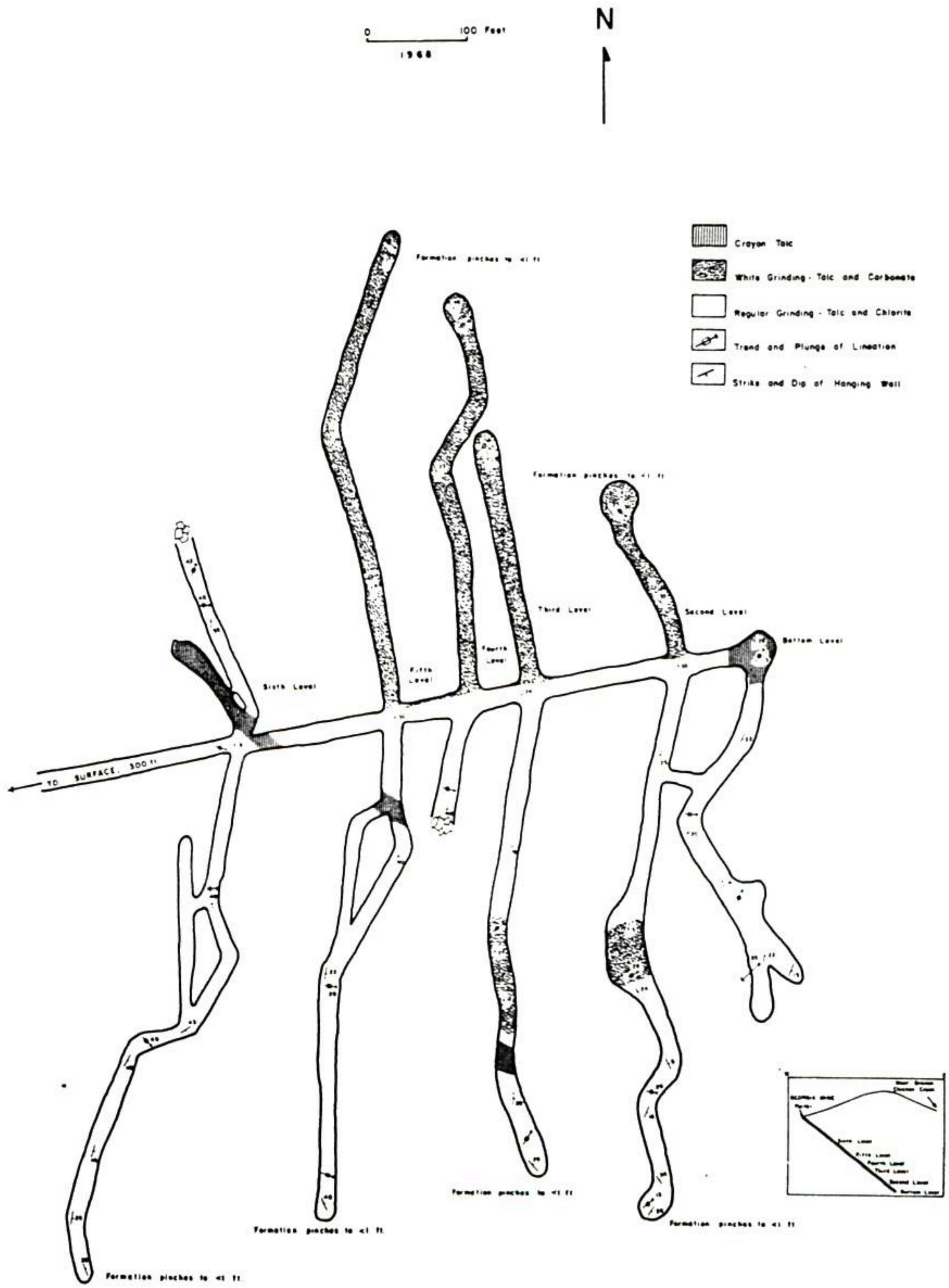


Figure 5

Because of complex folding and faulting, the trend of the talc is difficult to predict, and considerable test drilling is required before adits are driven. In general, the talc is aligned along the trend of lineations visible in the boudin structures. Typically the talcose rocks are more highly contorted than the enclosing biotite gneiss.

Mining

The recent workings and part of the older workings are shown in Figure 6. Passages are wide in the Earnest Mine and gentle in slope to accommodate the use of dump trucks. The talc is generally thick and is mined by taking up the floor in benches. Ceiling heights are up to 30 feet. Since the preparation of Figure 6, many of the branching passages have been joined to provide better ventilation and gentler truck routes. The mined ore is dumped into large capacity bins at the portal.

Despite the complicated structure, some regularities are apparent in the distribution of the various rock types. A body of pencil-grade talc is clearly indicated between Stations 35, 28, and 30, lower part of the map. Since the preparation of the figure, this talc pocket has been mined out to the limits of safety. Much pencil-grade talc has come from the lower passages of the Earnest Mine. At present, however, no reserves are proven.

The configuration of the workings in the Earnest and old Fort Mountain Mines illustrate graphically that the quest in the Chatsworth district is generally for talc of crayon grade. Thus leads are followed as they appear, and little attention is given to systematic mining development.

Future of the Earnest Mine

Systematic exploration is needed to guide future development. The complexity of local structures diminish the chances of successful development through hit-or-miss efforts. A detailed geologic map of all the workings and a series of closely spaced structure sections through the mined area should guide a drilling program.

Rock Cliff Mine

Location and History

This mine is on Gold Mine Branch 790 feet measured normal to the schistosity above the Old Cohutta Mine. It is immediately below the contact between the Fort Mountain gneiss and Ocoee quartzite.

Prior to development of the Rock Cliff Mine, two old prospects were known in this outcrop of Cohutta schist. The first formed a small overhang about 800 feet north of the branch. It was 10 feet deep and exposed a face consisting of chlorite rock (80%) containing thin irregular lenses of talc (20%). The waste pile at this prospect was small; presumably the poor quality of the ore discouraged further digging. The second, smaller prospect was on an exposure 1200 feet north of the branch. It was not explored deeply enough to expose fresh ore.

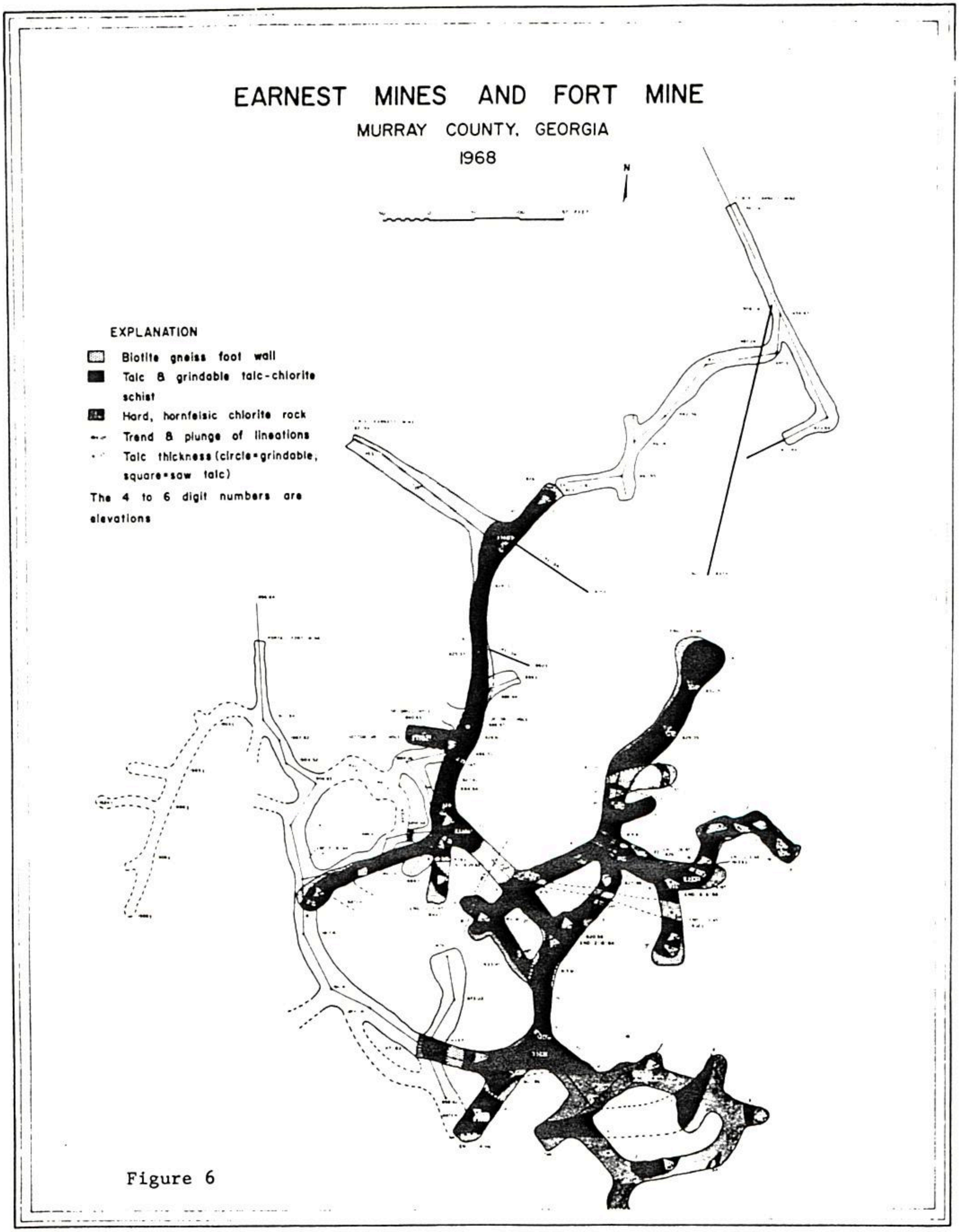

EARNEST MINES AND FORT MINE
MURRAY COUNTY, GEORGIA
1968
N
EXPLANATION
Biotite gneiss foot wall
Talc & grindable talc-chlorite schist
Hard, hornfelsic chlorite rock
Trend & plunge of lineations
Talc thickness (circle=grindable, square=saw talc)
The 4 to 6 digit numbers are elevations

Figure 6

In 1967 the Georgia Talc Company cut a road up to the two old prospects and began clearing from the first-mentioned prospect toward the south. About 1/3 the distance from the prospect to Gold Mine Branch a shaft was started on the talc and followed directly down dip a distance of 170 feet. The ore has improved at depth where it is at least as good as that from the Earnest Mine.

Mr. Needham located the base of the Ocoee quartzite on Gold Mine Branch and directed the clearing operations from the shaft to the branch. A continuous band of talc thereby has been exposed over a total distance of 1050 feet. Its thickness is 10 feet at the northern end, 12 feet at the shaft, 16 feet thick at a point about 500 feet north of the branch, and 4 feet thick at the branch. A second shaft has been started at the point of maximum thickness. Recent clearing at Gold Mine Branch shows the talc pinching off. Further clearing either to the north or the south will be difficult due to very thick talus accumulations.

Geology

The Rock Cliff Mine differs from every other prospect and mine in that the hanging wall is Ocoee quartzite rather than Fort Mountain gneiss. This upper contact probably is a fault that has cut off the gneiss above the talc, bringing talc into contact with quartzite. Evidence of faulting is abundant, as irregular quartz veins in the bottommost 10 feet of quartzite. Such signs of shearing would not be produced by the movement of quartzite over talc, but could have been produced by the movement of quartzite against gneiss. Thirty feet down dip in the second shaft, about 1 foot of slate belonging to the Ocoee series separates the quartzite from the talc. It is therefore possible that at depth the dip of the talc lens and Ocoee rocks will diverge and that a full thickness of talc will be preserved with the usual hanging wall of Fort Mountain gneiss.

Evaluation

The ore exposed by the stripping increases in quality southward toward Gold Mine Branch. At the point of maximum thickness, the deposit is about 3/4 talc and 1/4 chlorite. Straight-grained blocks of talc are large enough to be sawn into crayons. The grinding grade talc runs rapidly through the mills with less wear on the equipment than typical ore because of its high talc/chlorite ratio. Its softness is well shown by a comparison of drilling times: one set of 10-foot long holes at the Earnest Mine requires 6-10 hours, at the Georgia Mine 4-8 hours, but at the Rock Cliff Mine only about 2½ hours.

Both quantitatively and qualitatively the Rock Cliff Mine is the best talc exposure ever found in the Chatsworth district, with the possible exception of the Georgia Mine, where the original exposure was not quite as wide but equally thick and of similar high quality. At both the Georgia and Earnest Mines, operations have been carried to depths approximately equal to outcrop width, without bottoming. If the Rock Cliff deposit extends to a thousand foot depth, then more than a million tons of ore can be expected from the site.

Recommendations

The down-dip extension of the fault at the top of the talcose unit is completely unknown. Thirty feet down in the second shaft being driven, the fault is diverging from the talcose unit. The fault may be found to approach the talc at other places, even cut it off. Because of uncertainty as to the relationship of the fault to the talc at depth, a hardrock footwall adit is not recommended until the two existing shafts prove enough ore to warrant the developmental expense.

The down dip continuation and attitude of the talc might be explored by diamond drilling through the hanging wall; this approach is handicapped, however, by the location of the mine on the steep west slope of the mountain and the dip of the talc to the east into the mountain.

If the talc extends downward regularly as indicated by present exposures, and is not cut off by the hanging wall fault, the Rock Cliff Mine can be expected to become perhaps the best producer in the district.

Old Cohutta Mine

Four miles southeast of Chatsworth, south along strike from the Georgia Mine and the Judge's Hole Mine is the Old Cohutta Mine. It was opened prior to 1912 and was last operated about 1932. The only published description is that by Hopkins (1914, p. 260-261). The mine operated about twenty years after Hopkin's description. The workings are said to have been quite extensive, but all that remain now are two collapsed openings and the dumps. The Georgia Talc Company has reclaimed some pencil grade talc from the dumps. Whether the mine was abandoned for lack of ore or other reasons is not known. Local miners have suggested that abandonment was due to heavy ground, and not to the absence of talc (Furcron, Teague and Calver, 1947, p. 53).

Southern Mine

Three miles southeast of Chatsworth, on strike with and north of the Georgia Mine is the location of the Southern Mine.

The initial work was done prior to 1900, though little talc was produced until about 1917. For the next four years the mine was operated more or less continuously and then abandoned. The mine was reopened about 1935 and again abandoned about 1963. The workings near the surface are now caved and marked by a depression 230 feet across and about 100 feet deep. Apparently the ore was nearly exhausted before the mine was abandoned due to dangerous working conditions.

Earnest Prospect

Northeast of Chatsworth 4.7 miles, in Lot 244, on the northeast side of Fort Mountain, is the Warren Earnest Prospect. It is on the east side of Mill Creek, a short distance northeast of the old Mill Creek Mine.

Three shafts and numerous pits and clearings expose a talc lead about 1100 feet long. Near the middle shaft are iron tram-car tracks; near the southern shaft is a dump pile of several hundred tons of good quality grinding talc with much crayon-grade talc.

The accompanying geologic map shows that the Earnest Prospect is within the Mill Creek reentrant. The best material, determined by dump grade, is near the south shaft, i.e., toward the apex of the reentrant. The strike of the talc lead changes 30 degrees over the 1100 foot distance of the exposure; slope wash deposits cover both ends. The north end is close to the Fort Mountain gneiss-Ocoee contact; thus the talc body cannot continue more than 300 feet in this direction. Between the Earnest Prospect and the Mill Creek Mine, the creek and its tributaries have cut through the Fort Mountain gneiss and exposed the underlying Ocoee phyllite. Thus exploration is unlikely to uncover any additional talc between the two areas. The gneiss and the enclosed talc lead probably are truncated at shallow depth. Even so, the 1100 length of the lead and its high quality make the prospect promising. The down dip extent of the talc should be determined by drilling.

Mill Creek Mine

This abandoned mine is near the headwaters of Mill Creek, 4.5 miles northeast of Chatsworth, on the east slope of Fort Mountain. The property was first mined about 1890 and was last worked about 1915. The main shaft is on a scree slope between Mill Creek and one of its tributaries. Operations were never extensive and continuous production rarely lasted longer than 6 months. Reports are that the mine was shut down due to problems with flooding. The main shaft was 40 feet deep, at which point the talc was still stained.

Because the main shaft is now flooded and is located in scree, no talc outcrop can be seen. Fifty feet below the main shaft is a gneiss exposure, below which is a 3-foot thickness of highly weathered talc. A small tunnel has been driven into the biotite gneiss 1000 feet due north of the mine. Whether it intersected the talc body is not known. Talc and chlorite cobbles are farther north of the tunnel in a small stream, but the source of the cobbles was not located. The cobbles may have come from Prospect 125. On the west bank of Mill Creek, boxy gneiss is deformed into an anticline that plunges toward the mine.

This old mine is favorably located at a reentrant, but much of the drilling and clearing that have been done in the past were concentrated on the southeast side of Mill Creek where the gneiss has been eroded away and no talc could be discovered. Thus much of the search was futile. This site warrants further prospecting.

Prospect 125

Recent clearing with a bulldozer has exposed a talc vein at Map Station 125 (see geologic map). A collapsed footwall shaft is below the talc, and three small exploration pits are above the talc exposure. Along strike about 1300 feet to the north, next to the Earnest cabin, is a small talc exposure.

At the prospect the talc is 3 feet thick and surrounded by a thick aureole of boxy gneiss sapprolite. Collapse of the cleared area shows that underground workings exist at this point. Between Prospect 125 and the talc exposure at the cabin there appears to be little or no change in strike and dip of the country rocks. The talc float in a stream west of Mill Creek might have come from this site. Though the talc is relatively pure, the vein is narrower than at any producing mine, and there are no apparent structural anomalies to indicate the probability of the talcose unit being thickened. Thus this prospect does not appear promising at the present time.

Prospect 261

A new occurrence of talc not previously known has been found a short distance southwest of the Drip Spring Prospect, 80 feet south of the point where the power line crosses the road, at Map Station 261 (see geologic map). This talc outcrop is 4 feet wide and 14 feet long, and surrounded by slope wash on all sides. Thus neither the thickness nor the lateral extent of the talc have been determined.

The talc is of high grade with very little chlorite. Some boulders are straight-grained and soft enough to make crayons. The talc is near the lower contact of the gneiss and may be on the same lead as the Hammock Prospect.

This prospect is readily accessible and should be explored.

Drip Spring Prospect

The Drip Spring Prospect is between the Latch Mine and the Rock Cliff Mine. No shafts or pits are found here, but at one time crayon talc apparently was sawn off the outcrop, which is less weathered than usual. The talcose unit consists of jointed and fractured massive chlorite cut by thin talc veins. This chlorite-talc lead is transected by a road along which the chlorite/talc ratio is still high, and asbestos is common. The exposed material is subgrade.

Latch Mine

Northeast of Chatsworth 3.5 miles at the headwaters of the north tributary of Rock Creek, on Lot 296, is the old Latch Mine. This lot was prospected and a limited amount of talc mined about 1904. No production has been recorded since that time.

The talc lead is completely exposed over a distance of 450 feet and runs under slope wash at both ends. The lead consists of about 70% chlorite and 30% talc. The lead is 20 feet thick at the south end and 10 feet thick at the north end; the strike changes 25^{o} along the exposure, forming a shallow anticline plunging east.

A box of 7/8 inch cores has been abandoned above the talc cut; all consist of biotite gneiss. The cores were drilled in exploring the down-dip extension of the talc.

The bottom of the old ore bin is located near the top of the ore zone. Apparently mining was attempted above the talc lead.

The mine might have been improperly located. Still, the talc/chlorite ratio of the exposures is disappointingly low. Extensive prospecting would be required to determine whether the grade improves at depth.

New Cohutta Mine

East of Chatsworth 3.5 miles on the northwestern slope of Cohutta Mountain, in Lot 294, is the Cohutta Mine.

Mining was begun before the turn of the century. The early workings have been described by Hopkins (1914, p. 255-257). In recent years the principal workings have been on the south side of Gold Mine Branch. Mining was begun there during the early 30's and was more or less continuous until 1956 when the mine became inoperative. The workings extend about 600 feet down dip and 300 feet laterally. Mining was carried out on two levels, as at the Earnest Mine, with a splitter or gneiss between. For a description of the early workings and a map of the mines see Furcron, Teague and Calver (1947, p. 48-49). The mine was shut down in 1956 due to flooding, when the water table was reached.

The Cohutta Mine is favorably located in the Gold Mine Branch reentrant, and warrants further exploration. In particular, the talc can be traced 850 feet south to a prospect that has two 8-foot wide talc-chlorite zones separated by six feet of gneiss. The mine is reputed to have produced much white grinding talc and crayon talc. Underground test drilling was never extended more than 18 feet, as compared to the 50-200 feet of test drilling from working faces in the Earnest Mine.

Probably the ore has not been depleted at this site, and large reserves of high quality ore can be blocked out by systematic prospecting.

Big Lindsay Mine

The Big Lindsay Mine, formerly called the Fields Prospect, is 3.4 miles east of Chatsworth on the west slope of Cohutta Mountain on Lot 293. Near the beginning of the century a little prospect work was done at the site. The Big Lindsay Mine itself was opened, operated, and closed during the 1960's. The ore that was taken out was hard, chloritic, and contained very little crayon-grade talc. As at the old Fort Mountain Mine, double hoisting was required to bring the ore to the surface. The mine had been developed down dip for a distance of 350 feet when it was closed. The ore at depth was better than that mined near the surface.

Several prospect pits have exposed a 6-foot thickness of talc which extends

300 feet north from the old mine. The walls of the talcose unit are fresh and do not contain the weathered-out carbonate which is characteristic of most exposures. The Big Lindsay has been connected at depth with Prospect 236, and the best talc was found in this direction.

The Big Lindsay talc lead should be stripped along strike so as to determine the maximum thickness and the variations in quality of the ore. Any new tunnel should be driven to the north of the old mine, in the footwall.

King Mine

The location of the King Mine, formerly called the Pickering Mine, is 4.5 miles southeast of Chatsworth. It is the southernmost occurrence of talc in the Chatsworth district. The mine was opened in 1937 and abandoned shortly thereafter. The mine is unique in that the shaft was driven not in Fort Mountain gneiss but rather in knotty Ocoee phyllite. An extensive search of the dump discloses very little talc.

Three hundred feet above the horizontal entrance of the mine is a 5-foot band of quartzo-feldspathic rock resembling the Fort Mountain gneiss.

Reports of this mine are conflicting. According to Furcron, Teague and Calver (1947, p. 52), the ore was low quality. The dump bears this out. A mine operator reports that good ore was found but that operations were halted where the shaft intersected the talc. No underground drilling was done.

Sandy Gap Prospect

Southeast of Chatsworth 4.5 miles, on the north side of a small branch, is the Sandy Gap Prospect, formerly known as the Rock Creek Road Prospect. The talcose unit, which has been stripped by a bulldozer, is 5 feet thick and consists of about 70% chlorite and 30% talc, the latter in 1-2 inch thick layers. The length of the talc exposure is only slightly greater than its width. No trace of talc can be found in the two valleys that cross the lead north and south of where it has been exposed.

Neither the quantity nor the quality of the exposed talc encourages further development.

Chicken Creek Mine

Southeast of Chatsworth 3.7 miles, along a tributary of Chicken Creek, between the King Mine and the Old Cohutta Mine is the Chicken Creek Mine. It was first opened about 1937, but has long been abandoned. Two main openings were made. Hoisting shack, tramcars and an ore bin of 15 tons capacity mark the location of the old workings.

Talc outcrops and float can be traced both north and south of the Chicken

Creek Mine for a total distance of 3300 feet. Exposures of Fort Mountain gneiss, in which the talc occurs, are scarce, but can be found directly above one of the shafts and at the top of the ridge. Phyllite chips form an exceptionally heavy ground litter and may mask much of the gneiss. The strike and dip of the phyllite varies little over the 3300 foot distance, and the trace of the talc float shows the talcose unit to be relatively flat-lying. Talc is found on both sides of the stream. On the west side, talc forms a cap at the top of the ridge.

The quality of talc on the dump is high. This mine is reported to have produced a good grade of white grinding talc and much crayon talc. Thickness of the ore ranged up to 20 feet. No map of the underground workings was ever made, but miners have reported that the underground passages totaled only a few hundred feet.

Exploration by diamond drilling at this site would be relatively simple. The talcose unit is flat-lying; the overlying phyllites are soft and would be easy to drill; the gentle slopes allow ready access to a drilling rig. Drilling is desirable to show both lateral variations in thickness and ore quality down dip.

The prospects on the hilltop 1000 feet west of the Chicken Creek Mine are within 30 feet of the crest. The west slope of the hill approximates the dip slope, and weathered talc float can be found from the top of the hill all the way to the stream. This portion of the talcose unit could be readily prospected by drilling on the dip slope, and if found to be of commercial grade, it could be strip mined.

Judge's Hole Mine

The Judge's Hole Mine is along strike and about 1/8 mile south of the Georgia Mine. Since about 1939, it has been developed down dip for 400 feet contemporaneously with development of the upper levels of the Georgia Mine. The geology of the two mines is similar, but in the Judge's Hole Mine the talcose formation is thinner and harder and no white grinding talc has been found, the probable reason the mine was abandoned.

Recently, the Judge's Hole Mine has been pumped out for the purpose of connecting it with the Georgia Mine at depth. The still incompleted tunnel has been in grinding grade material all the way. One pocket of crayon talc has been discovered during tunneling, but not yet explored (Figure 7).

After the two mines have been connected at depth, it is expected that the Judge's Hole could be developed down dip to about the same depth as the Georgia Mine, although the quality of the ore is likely to be inferior.

Lower Bramlett Mine

On the southwest slope of Cohutta Mountain, on Lot 292, southeast of

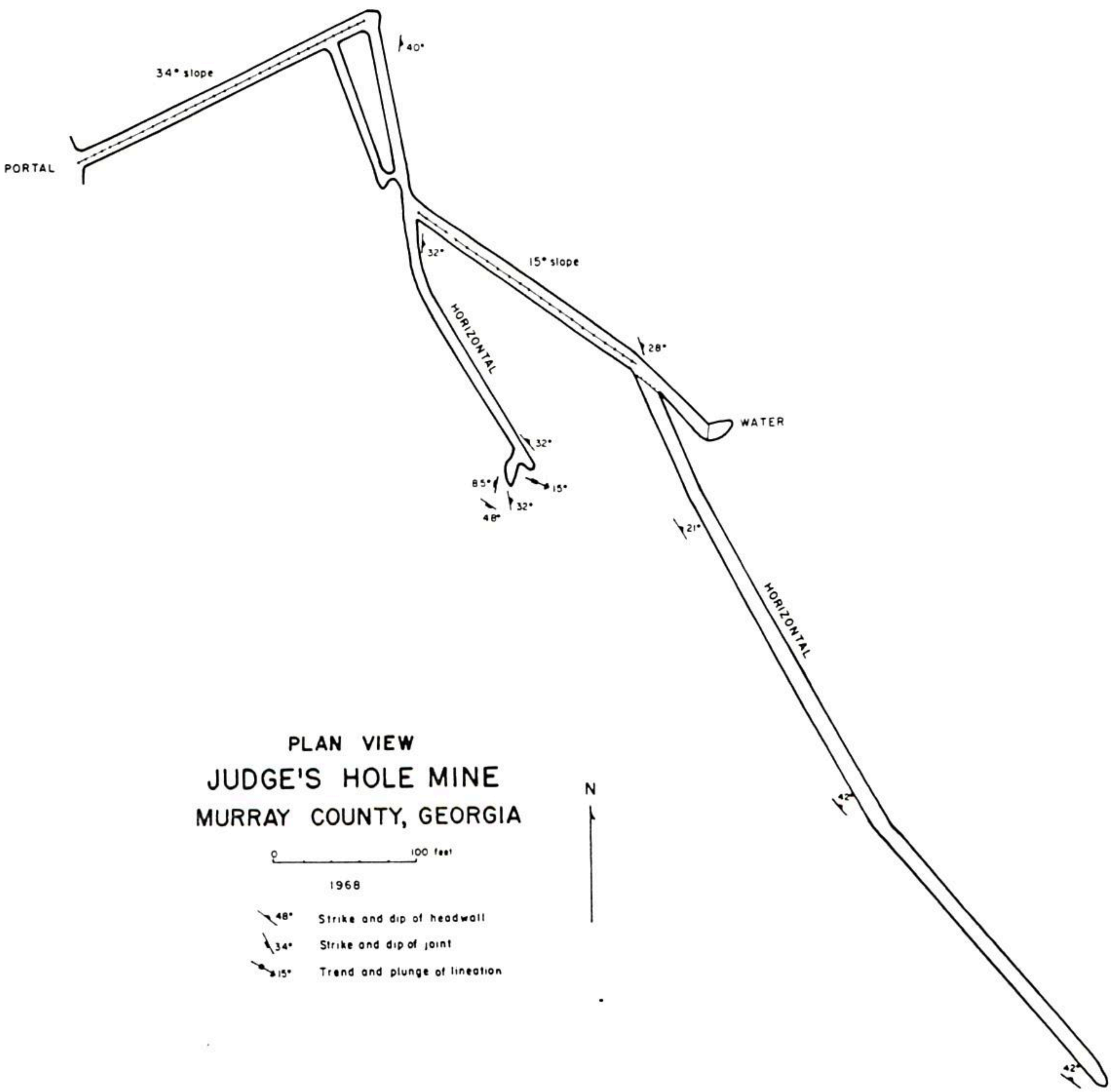

34° slope
PORTAL
40°
32°
15° slope
HORIZONTAL
28°
WATER
32°
85°
15°
32°
48°
21°
HORIZONTAL
42°
42°
PLAN VIEW
JUDGE'S HOLE MINE
MURRAY COUNTY, GEORGIA
0
100 feet
1968
48° Strike and dip of headwall
34° Strike and dip of joint
15° Trend and plunge of lineation
N

Figure 7

Chatsworth 3.1 miles, is the Bramlett Mine. It is just above and on the northeast side of Georgia Highway 52.

This mine was last operated in 1904. The talc body was 4-5 feet thick, striking due north and dipping 35^{o} east, and enclosed by Fort Mountain gneiss. Grade was reported to be low. The only remaining traces of the early workings are a collapsed, timbered shaft and a concrete winch base.

About 200 feet west of the shaft are two outcrops with about six feet of ore consisting of 50% talc and 50% chlorite. The talc is in layers thick enough to be sawn into crayons.

Despite good exposures on both sides of the mine, talc could not be traced.

Upper Bramlett Prospect

About 1/8 mile northeast and 600-700 feet above the Lower Bramlett Mine is the Upper Bramlett Prospect. A hard rock tunnel has been driven into the gneiss below the talc outcrop a distance of 50 feet. A short raise near the tunnel end intersects the talc above.

The talc outcrop above the tunnel is 3 feet thick and highly weathered. It is covered by heavy scree both to the north and to the south. Ocoee quartzite crops out above the talc, with gneiss float above the quartzite. The gneiss exposed in the tunnel is veined with quartz in an irregular pattern similar to the veining of the Ocoee quartzite at the Rock Cliff Mine. The veining in the gneiss and the deformation of the Fort Mountain gneiss-Ocoee quartzite suggest major faulting.

The thinness of the outcrop and its topographic and structural location discourage further prospecting.

Russell Prospect

This is located 3 miles east of Chatsworth on Lot 295, which is on the western slope of Fort Mountain.

Talc occurs against a head wall of Fort Mountain gneiss. The talc is not well exposed and its extension in both directions is covered by slope wash. Below the talc is serpentine containing asbestos-filled fractures and chlorite schist. The rocks within 10 feet of the talc are weathered to a boxy sapprolite due to the weathering out of carbonate. The thickness of the talc is indeterminable from present exposures.

About 100 feet stratigraphically below the prospect and from there to the prospect is the Fort Mountain gneiss. It contains numerous thin quartz veins similar to those that are below the Lower Bramlett and Earnest Mines.

Hammock Prospect

A limited amount of prospecting has been done on Lot 319, 2.6 miles due east of Chatsworth, on the west side of the road from Georgia Highway #2 to the Cohutta Mine. Two small shallow openings have been made in a rock which is largely chlorite schist. Most of the material dug from the pits is chlorite schist, and it appears unlikely that much talc was encountered. The openings are near the Fort Mountain gneiss-Ocoee contact. Fairly good exposures are on both sides of the Hammock Prospect, along strike. They show no talc.

DISTRIBUTION OF DEPOSITS

The field mapping has shown that every talc mine and prospect in the Chatsworth District is within the Fort Mountain gneiss. The gneiss occurs in two long belts; producing mines are located along both. East of the two belts, along the Chatsworth-Ellijay highway, is a lensoid mass of gneiss less than a half mile long in which no talc has been found.

There are 26 known occurrences of talc in the two gneiss belts. Three of the 26 currently are being mined. About half of the upper gneiss unit is covered by scree and slope wash deposits which may conceal undiscovered deposits of talc.

The largest talc bodies that have been exposed in three dimensions are sinuous sheets with thickness to width to breadth ratios on the order of 1:100:100. The sheets are conformable to the foliation of the gneiss in every case. In the lower gneiss unit, the talcose sheets occur intermittently along the strike of the foliation and in line over a distance of two miles. In the upper gneiss unit the talc occurrences are less linear, and the talc is found at different levels within the gneiss.

STRUCTURAL RELATIONS OF THE DEPOSITS

The dip of the foliation of the gneiss, and of both the schistosity and the bedding of the Ocoee rocks is uniformly to the east at angles of 30 to 40 degrees. The strike changes progressively from north to north 70° east going from the southern to the northern limits of the talc district, and thus defines a broad syncline plunging east. Two warps in the plunging syncline have produced reentrants at Gold Mine Branch and Mill Creek.

At the Georgia Mine, pockets of pure talc are found where a sudden increase in dip creates a flexure. The best talc exposure, the Rock Cliff Mine, is located on a local warp (reentrant) at Gold Mine Branch. The same is true at the Mill Creek Mine and the Earnest Prospect, neither of which is operative but where excellent pencil-grade talc is abundant. At the producing Earnest Mine there is an abrupt change in strike and dip. In all cases, thick talc bodies, and talc bodies with a high talc to chlorite ratio, are to be found associated with deviations from the regional structural pattern. Conversely, there are talc mines, superficially located on good leads, that have become inoperative when the talc either pinched out or the mine did not produce high grade material. Examples are the Upper and Lower Bramlett Mines, the Latch, Big Lindsay, and Prospect 222. These mines and prospects are located where the attitude of the Fort Mountain gneiss follows the regional trend (the Big Lindsay is on the southern edge of the Gold Mine Branch reentrant).

Thus the talc has been thickened, and the talc to chlorite ratio increased, where structural anomalies are present. The reason is that talc is highly incompetent compared to quartz-feldspar gneiss so that during deformation the talc is plastically displaced to the crest or trough of the fold produced. This process has also operated on a smaller scale within the mines to effect a separation of talc from schistose chlorite along flexures and talc from massive quartz-chlorite boudin structures at small folds within the mines.

On this basis, i.e., the presence of structural anomalies, predictions may be made on the worth of existing mines and prospects, and it may be recommended that talc prospects be cleared or drilled in the direction of structural anomalies where hidden by talus or slope wash.

This structural analysis is not as applicable to the mines and prospects of the lower gneiss unit, for here there is no noticeable folding along strike. However, gradual pinch outs delimit the lateral extent of the Southern, Georgia, and Old Cohutta Mines and it is possible to attribute the pinching to gentle changes in strike in these cases also. The dip in the lower unit is less regular. At the Georgia Mine, the largest talc pocket discovered is located on a flexure in the dip from a normal 35 degrees to 90 degrees.

Within the mines, small faults are marked by roof ridges of slickensided chlorite. The ridges trend in the dip direction. Structural control of talc emplacement is implied by the parallelism of chlorite-quartz boudins with the dip of the hanging wall. Softer grinding material is found between the elongated boudin structures. Hence the trend of lineations indicates the local direction of the soft grinding layers. This information may be useful in underground drilling to prove ore and for planning the location of pillars.

MINERALOGY

For the general mineralogy of talc see the ADDENDUM.

The Chatsworth talc is the massive variety and is more or less schistose. When in thin veins associated with dolomite the talc is foliated, silvery white to apple green in color and is nearly pure talc. This variety is limited in quantity. The bulk of the mined talc ranges from light green to dark green and contains a variety of impurities. Several grades are distinguished by the miners on the basis of the kinds and amounts of impurities.

Crayon talc or saw talc consists mainly of straight-grained talc with minor amounts of chlorite and other minerals.

Blue john is a term used by the miners for a material which has the appearance of crayon talc but which is too hard to saw because of the presence of certain impurity minerals, principally chlorite, quartz, carbonate, and pyrite.

White grinding talc is a mixture of minerals, principally talc and dolomite, which when ground produce a white powder.

Dark grinding talc is a mixture of minerals, essentially talc, chlorite, serpentine, carbonate and magnetite, which when ground produces a gray powder. In much of the dark grinding talc, chlorite or chlorite and sericite are principal mineralogical constituents.

For both the white grinding and the dark grinding talc, a distinction is made between soft grinding and hard grinding varieties. In the case of the white grinding talc, distinction between soft and hard grinding varieties apparently depends upon the ratio of talc to dolomite, grain size, schistosity, and mechanical condition. In the case of the dark grinding talc, distinction between soft and hard grinding varieties appears to relate primarily to the talc to chlorite ratio and to the other impurity minerals that might be present. In general the harder grinding varieties contain less talc.

Six chemical analyses by L. H. Turner, chemist, Georgia Department of Mines, Mining and Geology, are in Table 1.

MINING

The history of mining in the Chatsworth district may be considered in four stages.

In the earliest days of the district, from the 1880's until about 1910, mining was done individually and by hand. Only crayon talc was sought. When a pit became too deep for hand mining, a new pit was dug along strike from the first. These small operations account for the multitude of pits and prospects which contain only a few tens of tons of material on their dump piles.

During the second stage a dozen or so of the mines were enlarged. Shafts were sunk to greater depths, and tramcars came to be used. Still, only crayon talc was recovered and the lower grade talc-chlorite-carbonate rock was discarded on the dump.

With the advent of the automotive industry about the time of World War II, the market opened up for ground filler in tires. By the 1940's three grinding mills and numerous mines were producing both crayon and filler talc for diversified industries. Between 3,000 and 5,000 tons of waste material from previous mining was salvaged from the dumps and shipped to the mills.

The last stage dates from about 1960. Since then the mine passages have been enlarged to permit the use of dump trucks and front end loaders.

At present only three mines are operating, all belonging to Georgia Talc Company. The workings of the Georgia Mine extend to a depth of about 800

M-1 to M-6
from Bull 53, p. 34
Table 3

TABLE 1 - Chemical Analyses of Chatsworth Talc

	M-1 Air-floated talc (-325 mesh) from Southern Talc Co. Mill	M-2 Dust from crayon saws, Georgia Talc Co. Mill	M-3 "A-white" talc powder 98% through 200 mesh screen	M-4 Roofing granules (-35 mesh), from Southern Talc Co. Mill	M-5 Gray talc (80% through 200 mesh screen), Cohutta Talc Co. Mill	M-6 Roofing granules, (-32 mesh) Cohutta Talc Co. Mill
SiO_2	40.75	59.72	41.02	22.80	46.24	47.92
Al_2O_3	12.77	3.04	4.23	4.79	7.29	7.35
Fe_2O_3	9.59	5.22	5.85	8.71	7.15	26.82
MgO	20.50	27.93	28.60	30.41	26.00	26.00
CaO	3.69	0.90	4.76	5.94	4.76	4.14
Na_2O	0.00	0.00	0.00	0.00	0.00	0.00
K_2O	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.12	0.00	0.00	Tr	Tr	0.00
P_2O_5	0.06	0.00	0.00	Tr	0.02	0.00
TiO_2	0.15	0.00	0.00	0.00	Tr	0.15
S	0.13	0.08	0.21	0.22	0.07	0.09
H_2O	0.05	0.00	0.00	0.01	0.05	0.05
Ignition loss	11.37	3.19	15.51	27.28	8.37	7.51

feet. The workings in the Earnest Mine extend down about 925 feet. The Rock Cliff Mine, which was opened during this study, has been driven down dip a distance of 170 feet.

As in earlier years, the mines are not systematically developed. The principal quest is for crayon grade talc. The underground workings generally are concentrated where the crayon grade talc is found or is expected to be found. The map of the Georgia Mine (Figure 5) illustrates the general mining procedure. A main inclined haulage way is put down into the talc body; levels for stoping are turned off on either side of the incline. Where crayon grade talc is encountered along the levels, the grinding grade talc is mined from beneath it so that the higher grade talc can be broken loose with a mininum of shattering. Thus overhead stoping is the general practice. Sinuous passages commonly are developed through the search for crayon grade talc and through the necessity of maintaining a grade passable by trucks. Several facings may be worked simultaneously so that separate crews may drill headings and load blasted ore at the same time. A crew consisting of one foreman, two drillers, one loader and one driver can produce 150 tons of ore per day.

The ore is trucked about six miles to the mills in Chatsworth. The roads are passable in all weather except the road from the Rock Cliff Mine.

PROCESSING

The crayon grade talc, only a few percent of the mines' output, is hauled separately from the mines to the receiving floor at the mill. It arrives in masses weighing at least 20 pounds. The blocks are reduced by sawing (and turning) to the requisite crayon sizes, graded, and packed for shipment. The dust and scraps from the saws is ground into powder.

Most of the output of the mines is ground. The three mills that do the grinding are each complete and separate. Their equipment includes:

primary gyratory crushers,
hammer crushers,
roll mills,
high speed vertical mills,
air separators,
classifiers,
sifter screens,
rotary dryers, and
calcinators.

High speed vertical mills produce low micron size talc for the paint industry. Classifiers throw out coarse material from the roll mills for use as roofing granules. Filler is produced to individual customer specifications in sizes from 40 mesh to 325 mesh. The product is either bagged or shipped in railroad hopper cars.

The three separate mills are an advantage in producing diversified products with a minimum of contamination and set-up time. Chlorite, barite, slate, olivine and sericite from local and outside sources also are ground at the mills.

PRODUCTION

Talc was first discovered in Murray County about 1872. Shortly thereafter small scale mining began. No production figures are available prior to 1898. Production from 1898 until 1967 is shown in Table 1. The figures from 1898 until 1907 are the total talc produced in Georgia and include some talc produced from the Murphy Marble Belt in Fannin and Gilmer Counties. The figures are from the Bureau of Mines' Yearbooks and the Georgia Department of Mines, Mining and Geology.

TABLE 2 - Talc Production in Georgia

Year	Short Tons	Value
1898	639	$ 4,054
1899	1062	42,085
1900	6477	77,217
1901	693	4,717
1903	1012	9,042
1907	739	11,473
1908	455	7,261
1909	400*	6,800*
1910	1150	15,000
1911	1191	18,883
1912	1020	15,124
1913	990	25,916
1914	670*	14,000*
1915	498	12,050
1916	3080	88,364
1917	3819	94,314
1918	4000*	100,000*
1919	3000*	60,000*
1920	1174	48,248
1921	1025	15,000
1922	1506	40,042
1923	796	16,568
1924	1885	30,548
1925	5022	76,028
1926	4220	89,000
1927	3110	42,370
1928	4888	85,265
1929	5041	146,025
1930	3439	89,690
1931	3672	65,873
1932	2510	26,487
1933	3408	40,045
1934	6095	61,086

TABLE 2 - (cont'd)

1935	7315	81, 373
1936	11473	114, 545
1937	11984	148, 177
1938	15117	130, 595
1939	20090	177, 881
1940	20104	219, 959
1941	28511	364, 560
1942	29930	464, 160
1943	35210	396, 031
1944	30425	363, 342
1945	32433	296, 162
1946	36410	380, 477
1947	49441	673, 251
1948	53602	624, 644
1949	49338	580, 405
1950	70749	774, 148
1951	77895	823, 133
1952	56491	653, 144
		Value of mine production, crude
1953	57891	202, 619
1954	50536	176, 876
1955	53828	117, 656
1956	57916	122, 000
1957	49372	106, 000
1958	(Figures withheld to avoid disclosing confidential information of individual company)	
1959	53692	107, 000
1960	40200	88, 000
1961	47950	98, 000
1962	45940	96, 000
1963	42000	93, 000
1964	40400	135, 000
1965	44800	313, 000
1966	41000	255, 000
1967	46150	291, 700

Total about 1. 46 million short tons

about $15, 800, 000

*Estimated

Yearly production and average price per ton have fluctuated rather widely, but production has been continuous since 1898. The total talc produced exceeds 1.4 million short tons with a value of about 15.8 million dollars.

USES

The talc crayons are used in the steel fabricating and welding trades. Lines drawn on steel with talc crayons remain visible under the flame of oxyacetylene torches better than other marking materials.

The bulk of the ground talc is sold for filler in paint, rubber and insecticides and for use in ceramics and roofing. Lesser amounts are used in cosmetics, special lubricants and various types of dusting agents.

Filler materials are usually high bulk, low priced commodities and transportation costs are a critical factor in their economics. The Chatsworth district is favorably located to serve the southeast. Freight rates allow Murray County talc to compete with New England producers in markets as far North as Ohio and Pittsburgh, Pennsylvania.

GENESIS OF THE TALC DEPOSITS

The general distribution and sheet-like form of the talcose bodies suggests that they originated as a sedimentary rock. Further evidence is the fine undisturbed sedimentary banding exposed in the northern passages of the Georgia Mine. The mineral assemblages of the talcose zones are compatible with their origin through the metamorphism of a sediment. Apparently the parent magma of the Fort Mountain gneiss, which generally encloses the talcose bodies, intruded and engulfed a dolomite-bearing sedimentary rock, the remnants of which make up the talcose bodies. Some non-talcose phyllites are found just north of and along strike from the New Cohutta Mine. In the lower gneiss unit, the talc bodies are enclosed in quartzose metasediments to the extent that the gneiss is subsidiary in occurrence but always can be found. In the Earnest Mine, the Fort Mountain gneiss has split the talc body into upper and lower leads with a tongue of intrusive gneiss separating the two.

While it is clear that the general origin of much of the talc was through the metamorphism of a dolomite-bearing sediment, the massive chemical interchange between the talcose unit and the Fort Mountain gneiss apparent at some localities and the partial replacement of the gneiss by talc at others shows that all of the talc did not originate by simple metamorphism, and that all of it probably did not originate at the same time.

OCCURRENCE OF NEPHRITE JADE IN THE EARNEST MINE

Introduction

Jade, a tough, dense, translucent, usually green, semi-precious gem stone, may be composed of two different minerals. The rarer of the two is jadeite, a sodium-aluminum pyroxene. The more common variety is nephrite, a magnesium-iron amphibole. Gem quality nephrite is associated with larger masses of actinolite at the Earnest Mine.

Occurrence

Schistose, pale milky green actinolite is found in many of the mines of the Murray County talc district, associated with pockets and streaks of talc. The two minerals locally are pseudomorphous: a vein of talc may grade into a vein of actinolite of identical color and texture.

In the Earnest Mine actinolite is much more abundant than in the other mines. Masses weighing several tons have been removed as waste during the mining of crayon talc. Within the large masses of schistose actinolite are smaller masses of nephrite. Few of the masses found so far are more than six inches in their largest dimension.

The hard actinolite and associated nephrite have not been mined except where unavoidable. When test drills have encountered such hard zones, the drilling has been continued in other directions. Accordingly, less is known about the occurrence of actinolite and nephrite than of talc and its associated minerals.

The nephrite described here is from the waste pile at the Earnest Mine.

Color: Uniformly dark green, unmottled.

Hardness: 6.

Cohesion: Tough.

Fracture: Hackly.

Microscopic texture: The amphibole crystallites may be felted or aligned.

Optical properties: Biaxial negative, large 2V; $N_Y = 1.618$, $N_Z = 1.630$.

Mineralogic composition: The optical properties and the X-ray powder pattern identify the amphibole as actinolite.

The nephrite is exceptional in its uniform dark green color and lack of mottling. The samples which have been cut and polished are superior to much of the commercial California jade.

The Chatsworth jade's deep green color and high polish characteristics insure its acceptance as a semi-precious gemstone. Though not previously recognized in the district, it probably occurs in commercial quantities, and might be found in several of the mines.

The better quality nodules might bring several dollars per pound.

RECOMMENDATIONS FOR TALC EXPLORATION

The best prospects for discovering significant new talc deposits are the northward extension of the Rock Cliff Mine lead, the Earnest Prospect, Chicken Creek Mine, and the underground connection of the Georgia, Old Cohutta, and Judge's Hole mines.

Though further clearing at the Rock Cliff Mine is difficult, talc occurs beneath the Ocoee quartzite north of, and across a small branch from, the mine. This prospect should be cleared with a bulldozer and followed northward to determine the northern limit of the lead.

The Earnest Prospect contains high grade material at the south end of the lead. Drilling is needed to prove the ore downdip, because of the possibility that the thrust sheet is shallow in this area. The Earnest Prospect is inaccessible to a jeep. A road would have to be cleared.

Exploration at the Chicken Creek Mine should include draining and reopening the mine, and drilling the talc to the south to determine its thickness and downdip extent.

Neither drilling nor clearing is feasible at the Georgia-Judge's Hole-Old Cohutta area due to the steepness of the slope. Underground connections could pay their way because much of the mined material could be ground for filler. In particular, drifts should be extended to the south towards the Old Cohutta Mine where high quality talc was once mined. Power lines, air compressor, winch, and haulage shaft at the Judge's Hole are all in operating condition, and could be used to advantage if production at this location were increased.

ADDENDUM ON TALC

MINERALOGY OF TALC

The mineral talc is a hydrous magnesium silicate, $Mg_6(Si_8O_{20})(OH)_4$ with the stoichiometric composition of 63.4% silica, 31.9% magnesia, and 4.7% water. Small amounts of Al or Ti may substitute for Si, and small amounts of Fe, Mn, or Al may substitute for Mg, but the composition varies only a little. The reported wide variation is due to analyses having been made on talc contaminated by other minerals.

Talc is soft (easily scratched by the fingernail), has a greasy to soapy feel, a specific gravity of 2.58-2.83, and is resistant to acids. It occurs in foliated, granular or massive aggregates. Pure talc is white to silvery white. The substitution of Fe^{2+} for Mg^{2+} in the lattice yields various shades of green. Other colors can be imparted by included or intergrown minerals, as chlorite, sericite, quartz, calcite, dolomite, magnesite, tremolite, actinolite, pyroxene.

Foliated talc is a relatively pure mass of talc displaying prominent micaceous cleavages.

Soapstone is a compact talcose rock of variable composition but containing sufficient talc to impart to the rock a soapy feel. The talc content may be as low as 50%, but good quality soapstone will contain 75% or more of talc. The common associated minerals are chlorite, amphibole, pyroxene and mica, as well as pyrite, quartz, calcite, or dolomite. The color of soapstone generally is gray to blue or green.

Steatite sometimes is used as a synonym for soapstone. Commercially, the term denotes a massive variety of high grade talc suitable for making either block "lava" or ceramic bodies.

Agalite, french chalk, lava, talclay, talcose, verdolite, and mineral pulp are trade names for talc or talcose products.

Talc is valued for its extreme softness, high slip, lubricating action, opacity, whiteness when ground and fired, high fusion point, high specific heat, low heat conductivity, low shrinkage, resistance to thermal shock, chemical inertness, high dielectric strength, high absorption of certain oils and other liquids, good retention for filler purposes and ease with which it can be worked. For pharmaceutical, cosmetic and electronic uses high purity talc is preferred. For other uses the impurity minerals commonly associated with talc may be harmless or even beneficial. The great variation in mineral composition and physical properties of commercial talcs contributes to a wide range of uses.

Soapstone is valued for the ease with which it can be sawed or carved into slabs or structural shapes, its high electrical resistance to heat and acids, and its slow radiation of heat (Ladoo and Myers, 1951 and Irving, 1960).

GEOLOGIC OCCURRENCE

Talc is a secondary mineral derived generally from magnesium-rich rocks by either hydrothermal alteration or low grade thermal metamorphism. The differences in mineralogy and physical properties that characterize various talc deposits stem from differences in the parent rocks and the formational history of the deposits. The talc formed through thermal metamorphism of siliceous dolomites generally is whiter and purer than talc derived from the metamorphism of ultrabasic igneous rocks. Thus the highest quality "steatite grade" talc is usually associated with metasedimentary rocks, while soapstone is usually associated with altered igneous rocks.

Clues to the origin of a deposit are the minerals associated with the talc, particularly relic minerals, shape and distribution of the deposit, its structural relations, and trace element composition.

UTILIZATION

Historic Uses

The use of compact or block talc and soapstone can be traced back to man's earliest cultures. "Potstone" came to be used for household pots and utensils by primitive people in many areas of the world. It was readily available, easily shaped by the most primitive tools, resistant to heat and acids. "Potstone" still is used extensively in China and India.

Block talc and talcose rock were used by the Egyptians and Assyrians for carved scarabs, cylinder seals, and other signets and amulets. Talcose rocks commonly were used as building stones. The Cathedral of Trondhjem in Norway was built of soapstone around 1200 and is still in good condition (Eagle, 1947 and Irving, 1956).

For centuries the Chinese and Japanese carved art figures, vases, and ornaments from block talc. During the Ming dynasty (1368-1644 A.D.), the Chinese discovered that firing would harden and preserve carved objects.

In the early 1700's, talc deposits were discovered in Bavaria and became the source of heat-hardened talc bullets and cannonballs for many wars. Other uses soon developed for talc, as buttons and molds for glass and metal castings.

In 1751, talc found in association with serpentine in Cornwall, England, was used in the manufacture of old Worcester porcelain (Eagle, 1947 and Irving, 1956). By the middle of the 19th century pressed and extruded powdered talc bodies were developed and soon began to replace many of the sawed, carved, and machined shapes.

The early Indians of North America quarried block talc and soapstone for carving into various utensils. The early settlers in many states worked deposits to obtain soapstone for local use as foot warmers, utensils, and fireplace linings. By the 1870's, the manufacture of tubs, sinks, hearthstones, mantels, griddles, fire brick, and various utensils from soapstone and block talc had begun. About 1880 the first talc-grinding mill was established at Gouverneur, New York, to grind local talc for use as a paper filler.

By the late 1800's the output of the talc and soapstone industry of the United States was about 88,000 short tons per year (Irving, 1956). Bavarian and then Scandinavian talc was imported to the United States prior to 1900 for use in the manufacture of gas-burner tips and mantel supports. These imports continued until World War I, when they were interrupted and India became the principal import source.

Talc's value as an auxiliary flux was recognized soon after 1900 and small percentages were added to electrical porcelain mixtures to promote vitrification. Later, considerable tonnages of talc were used in the production of backwalls and radiants for gas-fired space heaters because of the mineral's good thermal shock characteristics. In the 1920's, the first high-talc wall tile was commercially produced and the use of talc in earthenware mixtures for dinnerware, artware, and wall tile increased rapidly as it was realized that talc imparted greater strength to glazed ware (Treischel, 1957).

With the advent and growth of the electrical industry block talc began to be used as an electrical insulating material. As voltages, frequencies and operating temperatures increased, previously suitable materials such as paper, mica, glass, rubber, porcelain, plastics and even lower grades of talc fell short of requirements and block steatite grade talc imported from India and Italy became the only suitable insulation material (Eagle, 1947).

Current Uses and Specifications

In 1966 about 30% of the talc and soapstone consumed in the United States was used by ceramic industries for high frequency insulators, regular heat and electrical insulators, wall tile and whiteware bodies. About 19% was used by paint industries, mainly as a paint extender. About 8% was used as insecticide carrier, and 8% in the manufacture of asphalt paper roofing. Smaller percentages were consumed as dusting or lubricating agents, filler in rubber, a filler or coating pigment for paper, cosmetics, sizing in cotton fabrics, tailor's chalk, steel marking crayons, coatings for foundry facings, rice polisher, and a variety of other uses.

Ceramics

The ceramics industry for many years has been the largest single user of talc and soapstone. Steadily increasing usage is due to research by the ceramics industry rather than by commodity producers.

Steatite ceramic bodies for high-frequency electrical insulation have the most stringent talc specifications. A talc is classed as steatite grade only when it is accepted by insulator manufacturers. Though most non-steatite talcs can be recognized by obvious impurities, some talc which is of steatite purity is not accepted for insulator manufacture because it does not meet specifications for fired color, fired shrinkage, and dielectric properties or has improper forming characteristics (Wright, 1957 and Irving, 1960).

Dielectric steatite ceramics are pressed or extruded into desired shapes and sizes from mixtures containing 70-90% ground steatite grade talc, clay and small percentages of alkaline earth oxides or carbonates and a gum. The bodies when fired at temperatures in the range of 2250°-$2450^{\circ}F$ become extremely hard and strong. Although insulators manufactured from ground steatite talc which is domestically available have generally replaced bodies machined from block steatite talc which is not domestically available, small quantities of block steatite are still required for the manufacture of tube spacers or insulators for vacuum power tubes.

Block talc of non-steatite grade is machined and fired for non-critical heat and electrical resistance uses such as insulators for electrical appliances, spark plugs and gas-burner tips.

The largest uses of talc in the ceramics industry are wall tile and whitewares, as dinnerware and artware. The use of talc instead of feldspar in wall tile bodies virtually eliminates the delayed development of minute cracks known as crazing. Talc for these uses must form well when cast or pressed, be homogeneous enough to assure uniformity in the dimensions of the finished products, and fire white.

Paint

Talc is an effective paint extender for several reasons: it reduces the rate of settling of mixed paint; its micaceous and acicular particles promote durability; it aids the dispersion of pigments and smooth flow. To be used as a paint extender, talc must grind white or nearly so. As a simple extender, it competes with ground silica, clays, and other inert, finely ground minerals. In the choice of talc for particular paints particle shape and particle size distribution are important factors (Wright, 1957 and Chidester et al, 1964).

For outside house paints talc is ground to 99% less than 325 mesh and used with a linseed oil base. Talc ground to minus 15 microns, or finer, is used in industrial enamels to control gloss. Ground talcs of steatite and near-steatite grade are used in emulsion paints (Wright, 1957). Fibrous talcs better remain in suspension, thus retard the separation and hardening of pigments in the can. Pure-white fibrous talcs can serve as pigment in cold-water paints. Tremolitic fibers in the talc tend to have an interlocking or bonding effect on the paint film. Foliated talc tends to give a plated structure to a paint film (Ladoo and Myers, 1951). In 1958, a patent was issued for a water-dispersible talc pigment (Irving and Brett, 1959).

Roofing

Talc and soapstone are used in the manufacture of prepared asphalt paper roofing chiefly as a surfacing material and as a dusting agent to prevent sticking when the roofing is rolled. Off-color talc is acceptable.

Insecticides

Talc and soapstone are used as carriers because they are cohesive, cheap, available, easily spread, soft and free from abrasive grains. They compete with clays and pyrophyllite (Ladoo and Myers, 1951; Wright, 1957; Irving, 1960). As with roofing talc, off-color material is acceptable.

Rubber

Talc is used mainly as a dusting or lubricating agent applied either as a dry powder or in a water suspension. It is used also to some extent as a filler in lower grades of rubber goods because of its softness and insulating properties and as a coating for rubber molds to prevent sticking (Ladoo and Myers, 1951; Wright, 1957). Off-color talcs that otherwise resemble talc of steatite grade are suitable.

Paper

Talc competes with clays as a filler and coating pigment for paper. Talc's advantage over clay is its higher retention in the finished paper; its disadvantages are the likelihood of poor color, higher grit content, and coarse grain size. The talcs most often used are steatite or near-steatite grade. Ground to 99% less than 325-mesh, the talc is used as a lubricating and calendering agent for high-quality paper, applied as the paper is passed through highly polished steel rollers; ground to 99% less than 5 microns, it is used as a pulp ingredient to impart opacity and brightness to the highest-quality paper (Wright, 1957).

Cosmetics

For this use talc must be light colored, chemically pure and have a pleasant feel. To be used as a face powder it must have uniform color tinting strength (Wright, 1957 and Chidester et al, 1964).

Other Uses

As a sizing in cotton fabrics, talc must be white and have minimal abrasive constituents.

Steatite grade talc is used for rice polishing and coating.

Talc is one of the few materials that will mark hot or cold metal and be visible when the metal is cooled or reheated. Steel marking crayons are cut from block talc.

Soft, pure talc finds application in cloth marking as tailor's chalk.

Talc is used as an admixture for certain cements, concretes, and stucco, including a flame-proof mastic (Irving and Brett, 1959), an unprimed, permanent, non-brittle joint-sealing compound which requires no water for application between building brick or block (Drake and Brett, 1961), a sealing and waterproofing compound for use in cracks, crevices or joints (Drake and Brett, 1963). Talc added to concrete slurries is believed to make the concrete more resistant to breakdown upon exposure to temperature variations around the freezing point (Drake and Brett, 1962).

Pharmaceuticals demand talc of the highest-quality: chemically pure, light-colored, with a pleasant feel.

Talc is used as a cleaning and polishing agent for peas, coffee beans, peanuts, etc. and as an abrasive for gunpowder grains and turned wooden articles such as knife handles. Talc and soapstone are used as fillers in soap, linoleum and oilcloth, gypsum and other wall plastics, window-shade cloth, plastics, asphalt and wood.

Talc and soapstone are used in the manufacture of fertilizers; instrument wire and cable-insulating compounds; refractories; vaults; in the dressing and manufacturing of leather and in the manufacture of composition floor and wall tile. Talc and soapstone are used as a component for some cup greases; as lubricants; as white shoe and glove polishes and cleaners; as an absorbent for oils, odors, etc; in the making of colored crayons; as a dusting agent in making candy and chewing gum; as a dusting for salami and as a finish for wire nails.

Ground talc or soapstone is combined with pulverized iron ore to form a granular tire ballast. A filler composition containing powdered talc stops the leakage of oil from transformers, X-ray apparatus and similar devices (Drake and Brett, 1960). Free-flowing dry fire-extinguishing compositions use 50% to more than 90% finely ground talc with or without dried ammonium sulfate, diammonium phosphate, a metallic stearate drying agent and an absorbent such as magnesium carbonate.

Because of its resistance to both high heat and chemical attack soapstone is used as a refractory material with no known substitute for the lining of some types of alkali recovery furnaces in kraft pulp mills. Slab soapstone is used for laboratory sinks, hods and table tops; acid-resisting tanks; kitchen sinks; laundry tubs; lavatories; structural units; electrical switchboards; griddles; heating stones for fireless cookers; and cores for electrical heating elements.

THE DOMESTIC INDUSTRY

Forty domestic producers were active in 1966. Eight of these accounted for 75% of the total output (Commodity Data Summaries, 1968). Production was centered primarily in the New York-Vermont area with 39%, California with 15%, and North Carolina with 13% of the total.

New York

The Gouverneur district in New York is the nation's leading talc-producing area. The deposits are sheetlike to lenticular zones as much as several miles long and 300 feet wide, with a downdip of more than 2,000 feet (Chidester et al, 1964). Most of the talc is mined by underground methods and marketed principally for use in ceramics and paint, but also for use as a lubricant and mineral pulp filler in various products, as rubber and floor and wall covering (Feitler and Stewart, 1963 and Feitler, 1964). The deposits are completely silicated and do not contain minable amounts of essentially mono-minerallic talc rock. In fact, the mineral talc commonly is subordinate in amount to tremolite in the milled talc product. The proportion of tremolite, anthophyllite, serpentine, and talc varies widely. Other minerals include quartz, calcite, dolomite, iron and manganese oxides, diopside, chlorite, pyrite, mica, feldspar, sphene, tourmaline and apatite; many of these constitute impurities and are avoided in mining. The commercial talcs are very white and range from flaky to blocky; particles range from nearly equant to bladed and fibrous (Chidester et al, 1964).

California

Most of the California talc is obtained from deposits in a 200-mile belt along the eastern margin of the state. About two-thirds of the output is obtained from irregularly shaped masses in the Southern Death Valley-Kingston Range Region, Inyo and San Bernardino Counties, where a carbonate member in the lower part of the Crystal Spring formation has been altered by diabase silks. The largest mass is about 5000 feet long, 10-80 feet thick and several hundred feet deep. Other production comes from altered Paleozoic sedimentary rocks and altered granitic rocks in the Inyo Mountains, and from altered metasedimentary and intrusive rocks in the Silver Lake-Yucca Grove area of San Bernardino County (Wright, 1957, p. 623-631). Most of the talc is mined by underground methods and marketed principally for use in ceramics and paint, but also as a filler, lubricating and calendering agent in paper manufacture, filler and lubricant in rubber manufacture, sizing for textiles, and polishing and coating agent in the preparation of rice. Very little block talc is mined.

TABLE 3 - COMPOSITION OF NEW YORK COMMERCIAL TALCS

	Mined talc zone	Footwall talc zone	"Fiber Vein"	"Micro Velva Talc"
SiO_2	59.80	66.23	65.74	74.00
Al_2O_3	0.57	1.05	0.78	1.71
Fe_2O_3	0.05	0.13	0.10	---
FeO	0.15	0.22	0.31	---
MnO	0.39	0.16	0.32	---
CaO	6.80	2.26	1.96	6.61
MgO	27.45	25.71	27.16	33.50
SO_3	0.07	0.01	0.02	---
Ignition loss	4.75	3.86	3.71	7.74
Water (105°C)	0.45	0.25	0.29	1.96
CO_2	1.18	0.56	0.71	2.61

Iron and manganese oxides, SO_3, and CO_2, when present in excess of the amounts shown constitute serious impurities for some markets. In general the companies in this district try to keep the CaO content between 3 and 7%, and the MgO content between 25 and 30%

Vermont

Most of the talc deposits in Vermont form concentric shells of talc-carbonate rock and talc rock around cores of serpentinite which vary greatly in size and are absent in a few of the deposits. Some deposits are irregular or tabular bodies within dunite, peridotite and serpentinite and are composed of talc-carbonate rock that locally grades into carbonate (magnesite) rock. The talc-carbonate rock and talc rock range from medium or light gray to dark gray and from massive or faintly schistose to layered or gneissic. In most deposits the talc particles in both the talc rock and the talc-carbonate rock are fine and shredded. Talc rock is minor in all the deposits and only in a few is it suitable for crayons. All the talc is high in iron and most of the commercial product contains appreciable carbonate. Three underground and one open-pit mines have produced talc for use in paper, rubber, textiles, paint, roofing, cosmetics, crayons and filler. Flotation beneficiation practiced at one mill yields a white product that contains 95% talc.

TABLE 4 - COMPOSITION OF VERMONT TALCS

	Crayon talc from Waterbury Mine, Moretown, Vt.	Gray talc, standard minerun product - Johnson Mine Johnson, Vermont	Flotation talc, Johnson Mine
SiO_2	60.48	42.73	59.15
Al_2O_3	0.82	1.17	0.26
Fe_2O_3	0.10	total iron 5.93	total iron 3.36
FeO	4.59		
MgO	28.52	33.16	31.34
CaO	0.02	0.10	0.15
Na_2O	0.00	--	--
K_2O	0.03	--	--
TiO_2	0.01	--	--
CO_2	0.00	4.74	1.76
P_2O_5	0.02	--	--
Cr_2O_3	0.26	--	--
NiO	0.20	--	--
MnO	0.09	--	--
CoO	0.01	--	--
As_2O_3	0.00	--	--
S	0.01	--	--
H_2O-	0.00	--	--
H_2O+	4.94	12.95	4.30

(from Chidester et al, 1964)

The Eastern Magnesia Talc Company's Johnson Mine has operated continuously since 1925 at an average annual rate of 54,000 tons with a ratio of ore hoisted to finished product of roughly 2 to 1. The ore is stoped by a combination of shrinkage and sublevel methods. In any 24 hour period the mill produces an average total of 14 grades of finished talc product. In 1960, 20% of the mine output was used for rubber, 10% for insecticides, 25% for roofing, 16% for paper, 6% for paint, 3% for asphalt filler and 20% for other uses (Burmeister, 1963).

The Johnson deposits consist of a series of pinching and swelling, irregular, tabular bodies which locally are complicated by the existence of tight folds and inclusions of country rock. The usual rock sequence from the center of a lense outward is a serpentinite core, grit (a miner's term for rock consisting of mixed talc and magnesite), talc, altered chlorite schist, and unaltered quartz-mica schist. Along a known strike length of 3,500 feet the deposit varies from a single talc lens to as many as 5 parallel bodies separated by septa of schist. The ore is predominantly grit with a specific gravity of 2.9 which results in a tonnage factor of 11 cubic feet per short ton in place (Burmeister, 1963).

North Carolina

Exceptionally pure, white talc suitable for many uses, especially cosmetics, paint, paper, textiles and ceramics, occurs in commercial deposits in dolomitic marble in Cherokee County, North Carolina. The deposits are lenticular or spindle-shaped and range in size from small pods to bodies 700 feet long and 140 feet thick. Most of the talc is flaky to slightly fibrous, but much is massive or blocky and fine-grained; the color varies from white through greenish-white to green, blue and gray. Virtually pure talc rock forms an appreciable part of most deposits and a relatively small but significant proportion is of crayon grade. Impurities are minor amounts of quartz, carbonate, iron oxide stain and rarely tremolite. Some of the talc is of steatite grade (Chidester et al, 1964). The ground talc is sold principally for textile and toilet preparations (Boyle and Stuckey, 1964).

TABLE 5 - COMPOSITION OF 4 NORTH CAROLINA COMMERCIAL TALCS
(Chidester et al, 1964)

	I	II	III	IV
SiO_2	61.60	63.07	61.35	58.54
Al_2O_3	--	1.56	4.42	--
Fe_2O_3	2.10[1]	--	--	3.60[1]
FeO	--	0.67	1.68	--
MgO	31.24	28.76	26.03	31.04
CaO	0.24	0.30	0.82	0.22
H_2O+	--	4.36	5.10	5.15
Loss on ignition	4.88	--	--	--

1. Al_2O_3 + total iron calculated as Fe_2O_3

Montana

In the Dillon-Ennis district of Montana talc occurs in lenticular masses that range in size from small stringers to masses several hundred feet in length, several tens of feet in thickness, and several hundreds of feet in vertical extent; they constitute the principal domestic reserves of near-steatite and steatite grade talc. The commercial talc ranges from nearly white through various shades of gray, green, and brown, but most is pale to medium green. Most of the talc is very fine-grained and blocky, but some is flaky and somewhat crumbly. Except for a minor proportion of chlorite, no magnesium silicate minerals other than talc have been observed. Iron oxides occur as stains on talc fragments and in the form of minute grains of very thinly disseminated limonite. Graphite is widespread but ordinarily constitutes a minor impurity. Some talc bodies contain subordinate masses of material that is subcommercial as it contains excessive amounts of incompletely altered dolomite, earthy iron oxide, or talc that is excessively iron stained or graphitic. The commercial talcs are mined from open-cuts mainly for cosmetics, paints, paper, and ceramics (including electrical insulators). The samples in Table 6 are from the Smith-Dillon Mine. Sample I is a massive white to pale green, opaque to translucent, fine-grained to dense talc rock with intermixed veinlets of gray and darker green talc; it contains scattered tiny flakes of graphite and some manganese oxide. Sample II is a white to pale green or cream-colored massive talc rock, predominantly fine-grained but with a variable proportion of disseminated medium-sized folia or plates of talc.

TABLE 6 - COMPOSITION OF TALCS AT THE SMITH-DILLON MINE, MONTANA

	Steatite grade	Sample I	Sample II
SiO_2	58.46	62.25	62.06
Al_2O_3	1.90	0.27	0.50
Fe_2O_3	0.84	0.71	0.67
CaO	0.30	.05	.05
MgO	31.78	31.13	31.12
K_2O	Tr	0.02	0.01
Na_2O	Tr	0.06	0.07
H_2O-	6.22	0.14	0.18
H_2O+		5.03	5.09
CO_2		Nil	Nil

(Chidester et al, 1964)

Texas

Extensive deposits of white-firing talc were discovered in the Allamoore district of Texas in 1944 associated chiefly with phyllite, with which the talc intergrades. The deposits are tabular masses as much as several thousand feet long and vary in width from a few feet to as much as 200 feet. The upper parts of the talc bodies at and near the surface are light-gray soft talc rock, commonly veined by earth and vegetable matter. At greater depths the talc rock is darker and harder and beds and lenses of chert and carbonate rock are the principal contaminants. The talc is mined in open pits, and selective mining and hand sorting are generally necessary. The talc is of superior ceramic grade, with excellent pressing qualities, early strength and good firing characteristics. The whole operation is very attractive commercially as most consumers are within 100 miles of the processing plants. Ninety percent of the powdered product is sold as ceramic talc for the manufacture of wall tile; 10% is sold for insecticides (Pence, 1955 and Chidester et al, 1964).

Maryland

Block talc of non-steatite grade is machined and fired for non-critical heat and electrical resistance uses as insulation for electrical appliances, spark plugs, and gas-burner tips. The Dublin quarries in Maryland are the principal and only sustained producers of this type of material. Both ground and block talc are produced from several irregular talc deposits, but because of high iron content the talc is not suitable for steatite uses (Chidester et al, 1964).

Virginia

The soapstone quarries of Nelson and Albemarle Counties in Virginia are the chief producing quarries of the United States. The deposits are tabular bodies as much as 180 feet thick and of undetermined length, although some have been exposed in quarrying operations for distances of 1,500 feet. The material consists of varying proportions of talc, from 5 to 85%; chlorite, from 5 to 50%; serpentine, trace to 25%; amphibole, trace to 50%; carbonate, trace to 25%; magnetite, trace to 25%; and pyrite, trace to 2%. Of the two principal types of material quarried, the "soft" soapstone contains the higher percentage of talc and is the preferred type; the "hard" soapstone contains the least talc and the most chlorite and amphibole. The soapstone is a massive, felted, medium- to fine-grained, gray-green rock, sometimes showing the schistose or layered structure or grain that is preferred for manufacturing. Of the total production of around 2 million tons, 80% has been in sawed and shaped slabs. Scrap and waste "soft" soapstone is ground and used in roofing, rubber and insecticides (Ladoo and Myers, 1951 and Chidester et al, 1964).

TABLE 7 - COMPOSITION OF VIRGINIA SOAPSTONE

	Soapstone	Alberene Stone from Alberene Stone Corp.
SiO_2	39.54	41.75
Al_2O_3	3.72	4.80
Fe_2O_3	3.62	14.04
FeO	7.12	
MgO	24.84	25.56
CaO	5.93	4.19
Na_2O	0.08	--
K_2O	0.00	--
H_2O-	0.02	--
H_2O+	5.04	10.22
CO_2	9.50	
TiO_2	0.27	--
P_2O_5	0.29	--
MnO	0.16	--

Mining

Because commercial talcs and soapstones vary greatly in mineral composition and physical characteristics, and deposits range from one or several relatively narrow, closely spaced bands to immense lenticular bodies hundreds of feet thick, mining methods also vary, depending largely on the size, shape, composition, and attitude of the deposit and the topography of the terrain.

Much of the talc mined in the United States is recovered by underground methods, but in many mines, especially in the southern states, the workings are not systematic and mechanization is not extensive. Underground entry is by adit, inclined shaft, or vertical shaft. When the excavation is entirely in ore and mine support is necessary, extra care is taken in timbering because of the slippery nature of talc. Some deposits are mined by open-stope and pillar methods, with rock bolting used where necessary. Ore recovery ranges from less than 50% to nearly 65%. Frequently, different grades of talc are mined selectively or hand sorted. One company in Gouverneur, New York, mines 9 grades of talc by selective loading from various stopes or development openings (Irving, 1960).

When the talc is of crayon, block, or block steatite grade, mining is done without explosives except for occasional light "loosening" shots. Heavier charges might shatter the talc or cause innumerable invisible fractures which would open to form hairline cracks during firing. The extreme care which must be exercised in the mining of block talc where as large blocks as practical are broken out carefully with bars results in a very low productivity per man per day; this is reflected in a price per ton of block talcs as much as 10 times that of talcs produced for grinding purposes (Eagle, 1947 and Irving, 1956).

Most California talc mines are worked by underground methods using ordinary blasting techniques, developing first by shallow drift-adits and then by inclined shafts sunk along or near the talc body. Drifts at 50 to 100 foot intervals along the shafts follow the talc bodies and are joined by raises that are enlarged into stopes. The pillars are left large in "heavy ground". The ore is fed by gravity into ore cars that are usually trammed by hand. In some of the larger mines mucking machines are employed in driving the level workings. In recent years diesel rock-moving equipment has been introduced. Some of the California deposits require little timbering; in others, especially those that are wide and contain abundant talc schist along irregular hanging walls, timbering has been a major expense. Square-set timbering is used in several mines with large stopes, and the use of roof-bolting techniques has increased in recent years (Wright, 1957).

Most of the mines in Vermont and New York are developed by inclined shafts from which levels are driven in each direction along the vein at vertical intervals of from 50 to 200 feet. When the vein is not over 15 or 20 feet wide, the drifts may be cut the full width of the vein, but if they are wider than 20 feet several such wide drifts may be cut with frequent connections between them, thus resulting in a sort of room-and-pillar method. Raises are put up at more or less regular intervals and at such an angle that the broken ore will run to the level below. These raises may be cut as large as 20 feet square and are often connected at the top. In this way as much of the ore as possible is recovered in large development openings. When the limits of the ore body are reached on a given level, part of the pillars may be mined out but enough ore is left standing in the pillars to hold the walls. Then the shaft is deepened and another level is started. When the ore body has been completely worked out the pillars farthest from the shaft on each level are mined out and as much ore as possible recovered, retreating toward the shaft from both directions until the walls cave so badly that the mine must be abandoned. With this method little timbering is used. Drilling is usually easy and done with light compressed-air hammer drills of the jackhammer type or with stoping drills.

In Georgia's Chatsworth district mine adits are driven into the footwall of the talc lens so that the talc body will be encountered well below the zone of surface weathering and staining. These adits often are sloped so mine cars will roll from them by gravity. The mines have only one haulage way and each uses a 16 to 24 inch gauge steel track. After the talc body is encountered, inclines are put down into the talc body from which levels for stoping are turned off on either side of the incline. In most of these mines the plan of mine levels has been erratic as the major quest was for talc of crayon grade and little attention was given to systematic mine development. Overhead stoping with a minor amount of underhand stoping is used, and the miners usually select the location of upstopes from a level by the presence of crayon grade talc. The more impure grinding talc is mined from underneath the crayon grade talc and then the crayon stock is broken down so as to get the minimum amount of shattering. Crayon grade talc usually makes up less than 5% of the ore produced.

Generally the roof of the deposits stands well and little timbering is required for support. Except during periods of unusual rainfall little water is encountered and one small air-driven pump is sufficient to keep the workings free of water. Carbide lamps carried by the miners provide underground light. Exterior equipment consists of a gasoline or Diesel-driven compressor to deliver air at 200 pounds pressure, storage room, magazine for explosives, and ore bins of 20 to 80 tons located to permit loading by gravity into trucks for hauling to the mill. One man is generally employed at the surface.

Underground 2 or 3 men drill and work the stopes or headings using 40 pound jackhammers held by hand or in a saddle. Holes are usually drilled 6 or 8 feet deep and loaded with varying amounts of black powder that produces less fines and a minimum amount of shattered ore; fuses and caps are used in blasting the holes. In some mines the broken ore is loaded by an air-operated Sullivan mechanical loader, other mines use hand mucking. When the mining is from stopes a mucking platform is built at the bottom of the stope from which broken ore is shoveled into mine cars. The crayon stock is separated from the mine run ore underground. Two men tram the loaded cars from the working headings to the foot of the haulage incline, and two men hoist and tram the ore cars from the head of the incline to the ore bins. Gasoline or air-driven hoists are used underground in the mines that have good ventilation. Air hoists underground or hoists operated from the surface are used in the mines with poor ventilation. The crude talc is hauled to the mills in company-owned 6 ton dump trucks, which have a life of only 2 or 3 years.

In Vermont, the Eastern Magnesia Talc Company's Johnson Mine operates from a 9x12 foot, 45^{o}-inclined shaft which has been advanced by both sinking and raising methods to the 400 foot level. From April 1940 to November 1959, 826,285 tons of ore were hoisted through this shaft. Exploration is conducted underground by cross-cutting or core drilling from development openings to discover parallel ore bodies (Burmeister, 1963).

Mining is a combination of shrinkage and sublevel stoping with the stopes left unfilled; rock support is usually not required. The ore is broken very unevenly but easily by drilling and blasting into a product of which about 80% is in pieces weighing less than 500 pounds. Movement of the broken ore along the scraper drift from the stope drawpoints to the chute raises is by means of double-drum tugger hoists driven by 10, 15, or 30 horsepower electric motors. The stope material is broken to a maximum size of 12 by 16 inches by a paving breaker and moil or by drilling and blasting short holes. Side-dump 1½ ton steel cars are loaded by a 5 cubic foot air-operated, 9 horsepower mucking machine and connected into 5-car trains which are hauled by a 1½ ton storage-battery locomotive. The cars are emptied into the ore or waste pocket by means of a pneumatically operated piston which is remotely controlled by overhead cables. Sections of 70 pound rail laid horizontally with 16-inch spacing serve as grizzlies over the shaft pockets, and the oversize ore is hand broken to pass them (Burmeister, 1963).

A gasoline-powered, 170 horsepower single-axle-drive tractor and a 2-axle semitrailer fitted with a 20 ton box-type hydraulically operated rear-dump trucks the ore to the mill over 4 miles of paved and 1½ miles of gravel road. A drop in elevation of 550 feet between the mine and the mill saves fuel (Burmeister, 1963).

The Eastern Magnesia Talc Company operates a mine in Waterbury, Vermont, where mining methods are quite different due to the fact that most of the grit or talc encountered is not competent and drifts frequently require heavy timbering. Self-caving methods are usually used, or where this is not applicable stopes are benched from inclined raises (Burmeister, 1963).

Operations in the Allamoore district of Texas consist of open pits. Some quarries utilize 2 or 3 benches with working faces ranging from less than 5 feet to 12 or 15 feet high. Other operations appear to consist of rather aimless earthmoving efforts with waste piled on extensions of the talc body. The talc bodies are first stripped and cleaned by bulldozers. Some properties originally had relatively clean surface exposures and required little stripping, but other localities had up to 30 feet of overburden. The overburden is mainly composed of soft unconsolidated alluvial or colluvial material and does not require blasting. Actual quarrying methods vary at different pits. In one pit a bulldozer equipped with a single-tooth ripper prepares a surface for power shovel digging. In other quarries, talc is gouged from a face by a power shovel without any previous breaking by blasting or mechanical methods. In another pit the talc is broken by blasting with 80% dynamite prior to digging. The shovels in current use are of either 1/2 or 3/4 yard capacity (Flawn, 1958).

The region's main mining problems are caused by surface contamination and the sporadic occurrence of beds and lenses of chert and/or carbonate rock within the talc body. The upper part of the ore bodies at and near the surface is a soft light gray material commonly veined by caliche and containing cracks and fractures penetrated by earth and vegetable matter. At great depths the talc is darker, harder, and contamination is not a problem. The beds and lenses of chert and carbonate rock within the talc are extracted and dumped. Some rough picking of deleterious material at the quarry is necessary to maintain a high quality product (Flawn, 1958).

The crude talc is loaded directly into trucks without any secondary blasting or crushing and transported to the railroad which in all cases is only a few miles away.

Massive soapstone for dimension stone and other uses usually is quarried, and the aim is to produce large, sound, rectangular blocks with a minimum of waste. Individual quarry dimensions depend on the width of the vein to be worked and the condition of the walls. In Virginia, the only current source of dimension soapstone in the United States, quarry depths range from 100 to 270 feet. Eighty to 90% of the soapstone removed is waste, due in part to pyrite which may become oxidized and discolor the stone and to hard spots which make sawing difficult, but due mostly to small cracks that cause the slabs to break. Large blocks are cut out by channeling machines, hoisted to the surface and loaded on cars for transportation to the mill (Ladoo and Myers, 1951 and Irving, 1956 and 1960).

Milling and Processing

Almost all talc and soapstone receive some treatment before marketing as the crude products have few end uses; a few consumers do prefer to buy the mined material and prepare it to their own specifications (Irving, 1956).

Milling methods vary more in detail and in size than in principle. The ore is dry or wet screened to remove fines and passed over a belt conveyor for hand removal of the larger pieces of waste and low-grade ore. Primary crushing in jaw or gyratory crushers is the next step, followed by secondary crushing in roller, rotary or disk-type crushers in preparation for milling (Irving, 1956).

Coarse products with particle sizes ranging from 40 to 100-mesh usually are produced in hammer mills, with or without air separation. For finer grinds — 100 to 325-mesh — of soft talcs, roller mills in closed circuit with air separators are usually used. Many roller mills are equipped with combustion chambers which permit simultaneous drying and grinding; some are equipped with magnetic separators. For more abrasive materials, such as New York talc, quartzite or silex-lined pebble mills with quartzite pebbles as a grinding medium are used. These mills are usually in closed circuit with air separators but sometimes are used as batch grinders, especially if products with finer particle sizes are required (Irving, 1956). In 1960, a precision grinder was patented that scavenges the abrasive gangue materials and at the same time removes the softer mineral particles upon reduction to the desired size (Drake and Brett, 1961).

Recently, fluid-energy grinding mills called "micronizers" have been used to make products of finer particle sizes than the above mentioned mills. Micronizers introduce steam or air under high pressure through nozzles around the periphery of a steel chamber into which the crushed ore drops through a central opening and where the particles are subjected to intense mutual bombardment which pulverizes them to sizes of less than 5 microns. The demand for extra finely ground or micronized talc is rapidly increasing (Irving, 1956 and 1960).

A method and apparatus were recently patented for controlling the density of talc particles in slurries in fluid-energy grinding operations. The addition of deflocculants such as tannin extracts or caustic soda in the fluid-energy grinding of talc and other soft minerals tend to keep the vapor-mineral mixture more flowable. The formation of silica scale on processing equipment during fluid-energy grinding of talc and similar materials is prevented by the introduction of a magnesium compound; the magnesium combines with the silica to form insoluble compounds that pass through the heating zone as solids (Drake and Brett, 1962). Slurry additives such as sodium hydroxide and sodium carbonate or ammonia and carbon dioxide also prevent scale formation in fluid-energy equipment during the grinding of talc and other minerals (Drake and Brett, 1961).

The increasing demand by consumers for greater uniformity in ground talc has resulted in new blending methods. One technique introduced by the Gouverneur Talc Company of New York involves the introduction of fluidized ground talc near the base of storage silos instead of the top. This essentially eliminates the problem of gradual segregation by particle size as the stored talc is continuously mixing as the silo is filled or emptied. The talc is withdrawn simultaneously through several ports around the bottom of the silo to maintain uniformity (Drake and Brett, 1962 and Cooper, 1964).

Crayons are sawed from selected, medium-hard, straight grained talc blocks with circular saws similar to those used in wood-working. Lumps of crude talc of uniform quality and free of cracks and fractures are squared, then sawed into thin slabs equal in thickness to the desired width of the crayons. For greatest strength, the length of the crayon should correspond with the grain of the talc. The thin slabs are cut to final form, sorted, and packed in small boxes for shipment. Crayons are made in several sizes, usually 5 inches long and from ¼" by ¼" to 1¼" by 3/16 inch, but the most common size is 5 inches by 1/2 inch by 3/16 inch (Ladoo and Myers, 1951 and Irving, 1956 and 1960).

Lumps of high quality talc are sawed into rough prisms by power-driven circular saws in preparation for further manufacturing processes as block or block steatite shapes and also to check the texture and quality of each lump. Those prisms not rejected are sawed into suitable blanks and then machined to the desired size and form by turning, grooving, threading, drilling, and tapping. For these operations the block talc must be completely dense, unfractured, soft, and free from grit. It must yield readily to the various machining operations and yet have enough natural strength not to break during the handling. After machining the dried shapes are fired, which converts the soft talc into a steely hard material having refractory and electrical-insulating properties dependent upon the original grade of the talc used. The firing shrinkage of most block talcs is 1% or less and the shapes have a smooth surface and clean sharp edges (Eagle, 1947).

Beneficiation

The great range in physical properties of natural talc deposits covers the requirements of almost all industrial applications. This has discouraged widespread interest in beneficiation in the past. In recent years, however, the depletion of higher grade deposits, the increasing industrial demands for higher and more specific grades, and the opportunity for producers to meet the more rigid specifications of higher priced talc commodities have created greater interest in the development of mineral-dressing techniques for talc.

Gravity separation during regular milling is limited by the small differences in specific gravity and grindability of talc and the more common accessory impurities. The utility of hand sorting is limited when the impurities are locked in finer sizes. Though magnetite and a few other minerals as garnet, can be removed readily by magnetic separation, many of the common impurities are not removeable by this means.

Talc has proven to be one of the more readily floatable nonsulfide minerals. Its wettability is decreased by a variety of frothers, fatty acids, soaps and amines. It floats so readily that emphasis may be on rejecting contaminants rather than floating talc (Frommer and Fine, 1956). High iron or calcium hinders talc floatation, as does the necessity of grinding finer than 200 mesh to liberate impurities.

The grinding of talc is better wet than dry, as dry grinding smears the talc over contaminating mineral surfaces. Wet ball milling in a porcelain-lined mill with porcelain balls or flint pebbles is a good way to prepare talc for flotation. In general, a talc which yields low recovery or requires more than two cleaners will be uneconomic, unless the extra processing is offset by low mining or transportation costs. Each deposit offers its own mineral-dressing problems. Types of crusher, classifier, flotation cell, reagent charges and the amount and type or retreatment must all be worked out to fit a given ore.

Prior to the froth flotation of talc by the Eastern Magnesia Talc Company at Johnson, Vermont, in 1937, little had been done to beneficiate talc. In 1948 the Johnson plant was still the only commercial talc flotation plant. In 1958 the Johnson plant ran 24 hours a day and each day produced an average of 14 grades of finished talc products: 9 by dry grinding and air classification and 5 by wet grinding and flotation methods. The mill operated on a 3 shift, 5½ day-per-week basis (Burmeister, 1963). The ore was fed by gravity to an 15-inch by 24-inch Blake-type jaw crusher set to a 2-inch opening and then is sent to dry storage or wet storage. The ore for dry grinding was dried, the moisture content reduced from 3-8% to less than 0.2%. Dry grinding and air classification in a pebble mill was varied for the size of product desired. The flotation process used 3 Wilfley-type concentrating tables after grinding and classification. Each table made 2 products: a high-gravity waste product consisting of a small quantity of nickel, iron and cobalt minerals and a concentrate product composed of 65 to 75% talc and 25 to 35% magnesite with a trace of iron sulfides. A petroleum monosulphonate flotation reagent acting as a dispersing, frothing and collecting agent was added to the talc-magnesite product from each table. Flotation was in 20 Fahrenwald-type cells. The flotation concentrate was dried and sent to pulverizing mills to be ground and classified into salable grades ready for packaging.

Experimental work on the foliated talc-quartz ores and the fibrous talc-tremolite ores of the Gouverneur district of New York has demonstrated that these ores can be beneficiated by flotation. Beneficiation of the latter yields a tremolite tailing product which can be used in ceramics (Ladoo and Myers, 1951). Pine oil and kerosene are adequate for foliated talc but reagents of the amine type are more suitable for fibrous talc. Soda ash enhances the separation.

Frommer and Fine (1956) have experimented with the flotation of talc from several areas. Cooper (1964) has reported processes for the froth flotation of very fine talc.

In 1957, Merck and Company marketed a high-quality synthetic talc, but the price limited its use to specialty items (Irving, 1960). In 1960, a process was developed to produce synthetic talc in bulk (Drake and Brett, 1961).

MARKETING

Because talc and soapstone are relatively low priced commodities and transportation costs are high, only those grades which command premium prices can be shipped appreciable distances from the mine or mill. For a given deposit the available markets are largely confined to the needs of local industry rather than to the wide range of uses for which the material might be suitable (Irving, 1960).

The largest markets are in the heavily industrialized districts east of the Mississippi River and north of Virginia and Kentucky, and in California. Most California talcs of all grades are sold and used in the state, but as most of the electrical insulation markets are on the East coast and the major textile industry of the country is in the southeastern part of the United States, some California talcs that are specially suitable and desirable for these uses are shipped across the country to these areas.

Competition for most markets is keen. For example, the Allamoore district in Texas markets talc to the ceramic wall tile industries from Mexico to Tennessee and yet still needs more markets to consume its production (Flawn, 1958). In some cases certain grades of talc have been sold below the cost of production in an effort to market a surplus. In general, the reserves and productive capacity of domestic talc and soapstone deposits greatly exceed the demand. A continuing problem for the industry is the need to develop new markets, especially for the lower and more plentiful grades. Another problem is the loss of markets to other low-cost materials such as kaolin, fuller's earth, limestone, diatomite, feldspar, and other inorganic substances.

IMPORTS AND EXPORTS

Although the United States is self-sufficient in all talcose products with the exception of block steatite talc (for which there is a substitute) and block pyrophyllite (Irving, 1960), large proportions of special varieties such as French or tailor's chalk and fine cosmetic talc are imported because of customer preference (Chidester et al, 1964). In 1962, imports ranged around 26,000 short tons for a value of $1,069,000; in 1963 the imported tonnage was about the same but the value was $1,088,000. Italy supplied 70%; France supplied 19% and Canada, 8%. In 1963, 16 short tons imported from India and 929 short tons from Italy were crude and unground talc. Ground, washed, powdered and pulverized talcs were imported from Canada and France. Italy sent 228 short tons; Japan 105 short tons; and Taiwan 2 short tons of cut and sawed talcs. Total imports for 1963 were 25,681 short tons (Cooper, 1964).

Imports decreased to 23,000 short tons in 1964, held at 21,000 short tons in 1965 and 1966, and increased to 35,000 short tons in 1967 (Commodity Data Summaries, 1968). The import sources during this period were Italy 60%, France 22%, Canada 12%, South Korea 4%, others 2%.

Exports of talc, soapstone and pyrophyllite increased in 1963 to 57,000 short tons, after 2 years of decline. Exports increased to 74,000 short tons in 1964, and have held at about 70,000 short tons each year since 1964. Much of the export is ground ceramic talc sent to Mexico from Texas (Cooper, 1964).

PRICES

The actual selling price is a result of direct negotiations between the buyer and seller and is dependent upon the quantity purchased, cost of transportation, supply and demand of the talc in question and a wide range of specifications, especially the type of talc, its purity and fineness of grind. The price ranges from \$2.50 to \$100.00 per ton (crude or ground) depending upon grade and degrees of preparation.

When milling is not done on the mine premises, the prices paid for crude talc at the mines is negotiated between the miners and the operators of the milling facilities and are dependent upon the cost of transportation to the mill, the supply and demand of the talc in question and the quality of the talc (Wright, 1957).

Crayons are sold by the gross. Special varieties of block talc are sold by the pound or by the piece (Chidester et al, 1964). Prices for ground talc are usually quoted by the short ton, f.o.b. at the mill (Chidester et al, 1964).

TAXES AND TARIFFS

As of 1968, no special taxes are imposed on the talc and soapstone industries, and no special government programs affect production.

Producers of block steatite are granted a depletion allowance of 23% for domestic and 15% for foreign talc. Producers of all other grades of talc and soapstone are granted a depletion allowance of 15% on either domestic or foreign production (Commodity Data Summaries, 1968).

Presidential Proclamation 3822 authorized reductions in tariffs in accordance with the Kennedy Round trade agreements of 1967. The first stage of tariff reductions applies to calendar year 1968 and became effective 1 January 1968. The Statutory Rates of Duty remain unchanged and continue to apply to certain designated countries.

Item	Statutory Rate of Duty	Rate of Duty 1/1/68
Crude and unground	25¢/lb.	2¢/lb.
Ground, washed, powdered or pulverized	35% ad valorem	10.5% ad valorem
Cut or sawed, or in blanks, crayons, cubes, discs or other forms.	1¢/lb.	4¢/lb.
Other, not specially provided for	35% ad valorem	21.5% ad valorem

GOVERNMENT INCENTIVE

The government provides through the Office of Minerals Exploration of the Department of the Interior up to 50% of approved costs for exploration of eligible deposits of block steatite talc.

GENERAL OUTLOOK

The consumption of talc and soapstone undoubtedly will continue to increase. Domestic reserves are adequate for the forseeable future for all grades except block steatite.

The replacement of talc by competing materials, as kaolin, fuller's earth, limestone, diatomite, feldspar, and others, appears to be increasing, but the extent of the substitution is not known.

Price increases for talc since 1954 have been fairly consistent with the increase in the general price structure. At the same time mining, milling and transportation costs have risen. Many producers are faced with steadily decreasing market areas and greater competition for their products, especially the lower and more plentiful grades.

The development of low-cost methods for improving the quality of talcose products toward more stringent chemical and physical specifications and for finer grinds might improve the competitive position of talc producers.

Further consolidations may be worked out to give producers the advantages of national sales, advertising organizations, and research.

Bibliography

Burmeister, H. L. (1963) Mining and milling methods and costs, Eastern Magnesia Talc Co., Johnson Mine, Johnson, Vt., Bur. Mines Inf. Circ. 8142.

Chidester, A. H., Engel, A. E. J., and L. A. Wright (1964) Talc resources of the United States, U.S.G.S. Bull. 1167.

Commodity Data Summaries (1968) U.S. Dept. of the Interior, Bur. Mines, Washington, D.C.

Crickmay, G. W. (1939) Geologic map of Georgia, Ga. Geol. Survey.

Drake, H. J. and B. A. Brett (1961) Talc, soapstone, and pyrophyllite in U.S, Bur. Mines Mineral Yearbook, Vol. 1, pp. 1199-1208.

Drake, H. J. and B. A. Brett (1962) Talc, soapstone, and pyrophyllite in U.S. Bur. Mines Mineral Yearbook, Vol. 1, pp. 1189-1195.

Eagle, J. E. (1947) Block Talc: Am. Ceramic Soc. Bull., No. 26, pp. 272-274.

Feitler, S. A. (1964) New Hampshire Area Report, U.S. Bur. Mines Mineral Yearbook, Vol. III, pp. 663-668.

Flawn, P. (1958) Texas miners boost talc output: Eng. Mining Jour., Vol. 159, pp. 104-105.

Frommer, D. W. and M. M. Fine (1956) Laboratory floatation of talc from Arkansas and Texas sources: U.S. Bur. Mines Report Inv. 5241, 5 pp.

Furcron, A. S., K. H. Teague, and J. L. Carver (1947) Talc deposits of Murray Co., Ga. Geol. Surv. Bull. 53.

Hayes, C. W. (1896) Geological description of the Dalton, Ga. quadrangle (unpublished manuscript in the files of the U.S.G.S.)

Hopkins, O. B. (1914) Asbestos, talc and soapstone deposits of Georgia, Ga. Geol. Sur. Bull. 29.

Irving, D. R. (1956) Talc, soapstone, and pyrophyllite in Mineral facts and problems: U.S. Bur. Mines Bull. 556, pp. 853-867.

Irving, D. R. and B. A. Brett (1959) Talc, soapstone, and pyrophyllite in U.S. Bur. Mines Mineral Yearbook, Vol. 1, pp. 1059-1068.

Irving, D. R. (1960) Talc, soapstone, and pyrophyllite in Mineral facts and problems: U.S. Bur. Mines Bull. 585, pp. 835-844.

Ladoo, Raymond B. and W. M. Myers (1951) Non-metallic minerals, McGraw-Hill Book Co., Ind., New York.

Pence, F. K. (1955) A commercially proven white-firing talc occurring in West Texas: Am. Ceramic Soc. Bull., Vol. 34, No. 2, pp. 122-123.

Treische, C. C. (1957) Availability and control of ceramic grade talc and pyrophyllite: Am. Ceramic Soc. Bull., Vol. 36, No. 5, pp. 177-178.

Vallely, J. L. and G. Peyton (1959) Georgia Area Report, U. S. Bur. Mines Mineral Yearbook, Vol. III, pp. 283-298.

Wright, L. A. (1957) Talc and soapstone in Mineral commodities of California: Calif. Div. Mines Bull. 176, pp. 623-634.